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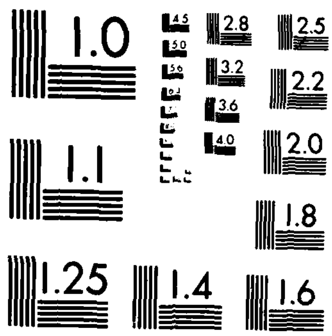
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FINAL TECHNICAL REPORT

REVIEW AND ASSESSMENT OF REDUCED EMISSIONS/CLEAN BURNING DIESEL ENGINES FOR INTEGRATION INTO THE ARMY INVENTORY

12 MAY 1983

SCIENCE APPLICATIONS, INC.

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12 MAY 1983

SAI 84-170-WA

Submitted to:

U.S. Army Mobility Equipment Research and Development Laboratories
Fort Belvoir, Virginia 22060

Authorization for this research was contract number DAAK70-81-D-0031, P0011. The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy, or decision, unless so designated by another documentation.

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12 MAY 1983

SAI-84-170-WA

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This effort examines the availability of diesel engines having reduced emission/clean burning characteristics for potential trial in 4000 lb. capacity forklift trucks to be used in closed and semi-closed environments.

The effort includes identification of substances which have been identified in diesel engine exhausts, health and safety considerations relating to those substances as established or recommended by U. S. and foreign governmental and professional agencies, and ranges of concentration of the substances which have been noted. (Cont.)

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Twenty-nine diesel engines which might be suited for use in 4000 (and 6000) lb. forklift trucks are characterized by manufacture-provided descriptive information and test data. A ranking scheme based on exhaust emissions and other parameters over a standardized work cycle was developed and applied to identify the candidate engines which appear most promising for the Army's application and, thereby, most appropriate for further testing.

Analysis of the data did not identify a candidate engine suitable for use in a closed environment without precautions or limitations for human exposure. These questions are to be subjects of further analysis and empirical testing.

SUMMARY

This effort examines the availability of diesel engines having reduced emission/clean burning characteristics for potential trial in 4000 lb. capacity forklift trucks to be used in closed and semi-closed environments.

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Analysis of the data did not identify a candidate engine suitable for use in a closed environment without precautions or limitations for human exposure. These questions are to be subjects of further analysis and empirical testing.

A

PREFACE

Valuable guidance was provided during the effort by Tim Lee (the technical representative), James Stephens, Stephen Sousk, and Paul Hopler of the Mobility Equipment Research and Development Command. Their timely input to and review of the engine evaluation scheme utility variables were especially helpful. The following also provided input to the study effort: Donald Emmig, OSD; Dr. Jim Coggins, Energy Applications, Inc., and numerous representatives from manufacturers.

The authors were assisted by the following other members of SAI in the preparation and review of this report: Seymour Kravitz, Lee Baumann, Bruce Gordon, William Schaeffer, and Bruce Berlage.

Assistance in formatting and presentation of the data and preparation of the report were provided by Terri Burcham and Nancy Davis of SAI.

Review and Assessment of Reduced Emissions/Clean Burning Diesel Engines for Integration into the Army Inventory

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SECTION I
INTRODUCTION

1.1 OBJECTIVE

The purpose of this effort is to determine the status, world-wide, of commercially available, reduced emission/clean burning diesel engines (RE/CBDE) and equipment suited to reducing unwanted emissions in Army material-handling equipment (MHE).

1.2 SCOPE

The objective stated above is addressed by the following subtasks:

1.2.1 Subtask a

Identify and describe diesel engine characteristics which contribute to reduced emissions and which must be considered in military closed and semiclosed (CSC) operational environments for MHE.

Determine from existing documents, the military and federal requirements for exhaust emissions in the CSC environment (or open environment) and diesel engine emissions as they interact in the CSC operational environment and the humans residing in such an environment. Where feasible, establish and document the bounds upon which chemical or irritant levels would impact military operations in the CSC environment. Where possible, document the levels of concern for short-term, long-term, and cumulative effects of operator exposure to the various pollutants.

1.2.2 Subtask b

Develop data from RE/CBDE manufacturers which will portray information about those engines which would be commercially available in April 1983. Provide manufacturers with questionnaries upon which to provide data pertaining to candidate

RE/CBDEs. Receive, validate, and perform data conversions as necessary, to place all data upon a common analytical base.

1.2.3 Subtask c

Analyze the engine data with the 'utility theory' technique as developed in close coordination with MERADCOM, and provide a rank-ordered list of engines based upon the RE/CBDE utility.

1.3 BACKGROUND

This effort is part of a comprehensive MERADCOM program directed toward development of a specification for the competitive procurement of clean burning diesel engine powered forklift trucks. This program is to gain the advantages of use of diesel engine powered forklift trucks over use of electric battery powered forklift trucks, especially: better sustained production performance; elimination of battery charging, associated equipment, and replacement batteries; and reduction of the number of different forklift truck models which must be procured. Actions in the program are identified in Table 1.1.

In a change of policy, on 7 January 1982, DARCOM removed the prohibitions on use of diesel-powered equipment in Richmond-type or earth-covered magazines provided: material in an area classified as hazardous must be handled by equipment rated by the National Electric Code for use in such area; industrial trucks are not used in certain munition manufacturing areas; and concentrations of combustion products and noise levels do not exceed the Army Surgeon General's standards. The change would be implemented as a change to TM 9-1300-206, "Ammunition and Explosives Standards." The National Electric Code is an element of the National Fire Codes, which provide explicit descriptions of forklift trucks authorized to operate in "hazardous" atmospheres. The codes do not define the hazard by the nature of material which may be present (such as explosives), except to the extent that combustible gases, dust, or material may be present. Extracts of the codes are at Appendix B.

Table 1.1 Actions Involving Replacement of Warehouse and Depot Forklifts with "Clean-Burning" Diesel Powered Forklifts

Army Depot Evaluation, USAREUR (Clark Forklifts)	Apr-Jun 1978
Draft Required Operational Capability (ODC) Prepared by 60th Ordnance Group, USAREUR	Oct 1978
Industrial Hygiene Special Study #8152-14-0002 Still Forklift, OLFEN, Federal Republic of Germany	Nov 1980
Evaluation "Still" (Brand) Diesel, Exhaust Hazard, Ramstein AFB, Federal Republic of Germany	Dec 1980
DARCOM Policy Change (See para 1.3)	Jan 1981
Industrial Hygiene Special Study #8152-14-0007 "Still Forklift Ammunition Depot, USAREUR	Feb 1981
Request for Technical Support from Environmental Health Agency (AEHA) to Prepare a Specification (MERADCOM)	Mar 1981
Draft Required Operational Capability (ROC) Prepared by Missile & Munitions Center & School (MMCS)	Apr 1981
MERADCOM Power Sources Test	1981
Identified "Clean-Burn" Still Diesel During USAREUR Visit	May 1981
Initiated Literature Survey	July 1981
Initiated Effort to Obtain "Still" Truck	July 1981
Performed Preliminary Hazard Analysis of "Clean Burning Diesel"	Aug 1981
Convened Meeting - Safety of Using Internal Combustion Powered MHE	Sept 1981
Clean Burning Diesel Forklift Demonstration, USAREUR	Oct 1981
User Survey of "Baker" (Brand) Forklifts with "Duetz" (brand) Engine	Oct 1981

Table 1.1 Actions Involving Replacement of Warehouse and Depot Forklifts with "Clean-Burning" Diesel Powered Forklifts (Cont.)

Attended "Clean Burn" Diesel Demonstration, Ramstein AFB, Federal Republic of Germany	Oct 1981
Tested "Baker" Forklift with "Duetz" Engine	Nov 1981
Initiated Test Planning	Nov 1981
Requested Technical Support from AEHA	Dec 1981
Negotiated Loan of Still Truck	Dec 1981
Forwarded Requisition for Leasing Used "Baker" Forklifts with "Duetz" Engine	Jan 1982
Tasked SAI for the Effort Covered by this Report	Apr 1982
Requested Department of the Army Chief of Staff to Identify Magazine for Igloo Test	May 1982
Prepared MERADCOM Comments to Draft ROC	May 1982
Prepared Basic Order of Issue Plan (BIOP) Feeder Data	May 1982
Tasked Southwest Research Institute for Measurement and Analysis	_____ 1982
Tasked Energy Applications, Inc. for Modeling of Diesel Engine Exhausts	____ 1982
Convened MHE Information Briefing for Industry and Presented "Clean-Burn" Program	Nov 1982

<u>PROJECTED ACTIONS</u>

Test Forklifts with Candidate Engines

Develop Coordinated Position on Safety Standards

User Survey

Prepare Specifications

Procurement

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MERADCOM is the material developer for the "clean-burning" forklift. The Army's fleet of the types of forklifts that would be replaced by the "clean-burning" forklift is old. The Army currently has seven makes and twenty models in use. The Army Material Plan calls for a standarized fleet through new procurement of a single model 4000 lb forklift by FY 88. MERADCOM has recommended that the M474-type MHE be fully replaced and the M492-type MHE be partly replaced by RE/CBDE-powered forklifts. There are further possibilities that the pneumatic and solid rubber-type tire 6000 lb forklifts may also be recommended for replacement by a RE/CBDE-powered forklift.

The Army has a fleet of approximately 10,000 general warehouse and depot MHE which may be candidate applications clean-burning diesel engines. About 1/3 are electric and the remainder are gasoline powered. The Army also has a fleet of diesel engine powered rough-terrain forklift trucks. All of the trucks are of critical importance in mobilization, build-up, and in the continued supply and support of all of the theater forces. Equipping the forces with MHE capable of sustained heavy operation in a multitude of potential environments and on a variety of surfaces would be a major improvement in Army readiness.

SECTION II
EMISSION REQUIREMENTS

2.1 DIESEL ENGINE EMISSIONS

A single source identifying all of the components of diesel engine exhausts has not been found. Further, principal source documents do not use the identical terminology or names for substances. Thus, "hydrocarbons" (HC) may be identified as a group, "aldehydes" may be identified as a HC subgroup or as a separate group, and in some sources individual aldehydes may be identified. There are HC emissions which apparently only occur as particulates. There are also HC which occur following breakdown or combination of other substances in the exhaust, but which are apparently not present in the initial exhaust.

Table 2.1 lists substances which have been identified in diesel exhausts. Data sheets which contain readily available information on most of the substances (some of the trace particulates have been omitted) are at Appendix C. Substances for which data sheets are not included are so noted in Table 2.1.

2.2 REGULATED EMISSIONS

It is DoD policy to follow Federal and State regulations and guidelines in the USA, to follow host country requirements outside the USA (Executive Order 12088), and to abide by the Clean Air Act as implemented. As a result, DoD does not separately promulgate emission or concentration limits.

The current Federal emission standards for diesel engines are based on vehicles and are stated on the basis of allowable limits in the nitrogen oxides, hydrocarbons, and particulates per mile or kilometer. These limits are shown in Table 2.2. There are no Federal limits on odor levels, apart from limits on the groups of substances which may be found in diesel exhaust.

Table 2.1 Substances Identified in Diesel Engine Exhaust

Substances marked with # are included in the National Toxicology Program 1981 list of 88 carcinogens (Reference 55).

Substance (Common Name)	IUC Name	Group
Acetaldehyde	Ethanal	Aldehyde
Acetone	2-Propanone	Keytone
Acetylene	Ethyne	Aliphatic HC
Acrolein	Propenal	Aldehyde
*Anthanthrene	--	Polycyclic Aromatic HC
#*Benz(a) anthracene	--	Polycyclic Aromatic HC
Benzaldehyde	Benzenecarbonal	Aldehyde
#Benzene	Phene	Aromatic Alcohol
*Benzo (ghl)perylene	--	Polycyclic Aromatic HC
#*Benzopyrene	Benzo-Alpha Pyrene (BaP)	Polycyclic Aromatic HC
1, 3-Butadiene	Vinylethylene	Aliphatic HC
Butane	Butane	Alkane
-Butylene	1-Butene	Alkene
-Butylene	(trans) 2-Butene	Alkene
Butyraldehyde	1-Butanal	Aldehyde
Caproaldehyde	Hexanal	Aldehyde
Carbon Dioxide	Carbon Dioxide	Inorganic
Carbon Monoxide	Carbon Monoxide	Inorganic
*Chrysene	1, 2-Benzophenanthrene	Polycyclic Aromatic HC
Crotonaldehyde	(trans) 2-Butenal	Aldehyde
*Cyclopentano c,d pyrene	--	Polycyclic Aromatic HC
Diazomethane	Azimethylene	Aliphatic HC
#*Dibenz a,h anthracene	--	Polycyclic Aromatic HC
#*Dibenzopyrene	--	Polycyclic Aromatic HC

Table 2.1 Substances Identified in Diesel Engine Exhaust (Cont.)

Substance (Common Name)	IUC Name	Group
2, 3-Dimethylbutane	2, 3-Dimethylbutane	Alkane
2, 3-Dimenthylpentane	2, 3-Dimethylpentane	Alkane
2, 4-Dimethylpentane	2, 4-Dimethylpentane	Alkane
Ethane	Ethane	Alkane
Ethylbenzene	Ethylbenzene	Aromatic Alcohol
Ethylene	Ethene	Aliphatic HC
p-Ethyltoluene	1-Ethyl-4-Methylbenzene	Aromatic Alcohol
#Formaldehyde	Methanal	Aldehyde
Heptane	Heptane	Alkane
Hexane	Hexane	Alkane
Isobutanal	2-Methylpropanal	Aldehyde
Isobutane	2-Methylpropane	Alkane
Isooctane	2, 2, 4-Trimethylpentane	Alkane
Isopentane	2-Methylbutane	Alkane
#("soots")*Lampblack	Amorphous Carbon	Basic Element
Mesitylene	1, 3, 5-Trimethylbenzene	Aromatic Alcohol
Methane (Marsh Gas)	Methane	Aliphatic HC
Methylacetylene	Propyne	Aliphatic HC
Methylcyclohexane	Methylcyclohexane	Aliphatic HC
Methyl Isobutyl Ketone	Hexone	Ketone
2-Methylpentane	2-Methylpentane	Alkane
#(?)*Nickel Carbonyl	--	Inorganic
Nitric Oxide	Nitric Oxide	Inorganic

Table 2.1 Substances Identified in Diesel Engine Exhaust (Cont.)

Substance (Common Name)	IUC Name	Group
Nitroethane	Nitroethane	Aliphatic HC
Nitromethane	Nitromethane	Aliphatic HC
*Nitrogen	Nitrogen	Basic Element
Nitrogen Dioxide	Nitrogen Dioxide	Inorganic
Octane	Octane	Alkane
*Oxygen	Oxygen	Basic Element
*Ozone (Secondary Product)	Ozone	Basic Element
*Peroxyacetylnitrate (PAN) (Secondary Product)	--	
Pentane	Pentane	Alkane
2-Pentanone	Methyl-n-Propyl Ketone	Ketone
*# -Propialactone	-Propialactone	--
Propylene	Propene	Olefin
*Steam	--	Inorganic
Sulfur Dioxide	Sulfur Dioxide	Inorganic
Toluene	Phenylmethane, Methylbenzene	Aromatic Alcohol
1, 2, 4-Trimethylbenzene	1, 2, 4-Trimethylbenzene	Aromatic Alcohol
*Water (Vapor, Aerosol)	--	Inorganic
m-Xylene	1, 30-Dimethylbenzene	Aromatic HC

*No data sheet at Appendix C.

Table 2.2 Federal Limits on Diesel Engine Exhaust
(Highway Vehicle Usage Only)

Component	Light Duty Diesel Engines (e.g., Automobile) (1978 Statutory)	Heavy Duty Vehicles (above 10000 lb. GVW)
Nitrogen Oxides (N_2O, NO, NO_2)	1.0 gm/mile	NO_2 - 7.5 gm/bhp-hr (1977 Calif)
Exhaust HC	0.41 gm/mile	1 gm/bhp-hr (1977 Calif)
Carbon Monoxide	3.4 gm/mile	40 gm/bhp-hr.
Particulates		
1983-1984		1.61 gm/mile
1985 and beyond		1.31 gm/mile
HC + NO_2		16 gm/bhp-hr (1974 Federal)

2.3 ENVIRONMENT CONCENTRATION LIMITS

Federal limits on the permissable level of toxic and hazardous substances are established by the Occupational Safety and Health Administration (OSHA) and published as Federal Regulations. Those substances which have been identified in diesel exhaust (Table 2.1) for which Federal limits have been so set forth are listed in Table 2.3. The limits are established on the basis of the substance being the only toxic or hazardous substance present. Allowable concentration levels of combinations of listed substances are treated by simple addition of the fraction formed by the concentration of the individual gases over their respective individual concentration limits (see the example at the end of the Table 2.3).

The concentration limits shown in Table 2.3 are for the environment to which persons are subject. Except where absolute limits have been stated, the concentrations are for a weighted average over a full work shift. The actual concentration levels could be much higher, but could still be within acceptable limits if all human exposures were for shorter durations than the 8-hour work shift basis and the weighted average of times of exposure did not exceed the calculated limits for the combined gases. Conversely, exposure for longer shifts than 8 hours and for work weeks longer than 40 hours would require proportional reduction in the allowable concentration levels.

Limits on concentrations of mineral dusts are established by OSHA and published in the Federal Register with the limits on gaseous toxic and hazardous substances. None of the particulates identified in diesel engine exhaust are included on the OSHA list; however, absolute limits for total inert or nuisance "dust" are presented: 15 million particles per cubic foot and 5 mg/m^3 of the respirable fraction and 50 million particles per cubic foot and 15 mg/m^3 of total dust. These limits are for time-weighted average exposures over a full 8-hour work shift of a 40-hour work week, as for gaseous contaminants. The table is not specific, but it is considered that amorphous carbon (lampblack) and liquid aerosols which are in diesel exhausts do not constitute "dust" as used in the OSHA table.

There are other limits on particulate concentrations which are not restricted to "dust." The national ambient air quality particulate standard (reference 26) is 75

Table 2.3 Federal Limits on Exposure to Contaminants

Extract of Code of Federal Regulations Chapter XVII - Occupational Safety and Health Administration, 1910, 1000 Subpart Z - Toxic and Hazardous Substances

a. OSHA Limits on Air Contaminants Found in Diesel Engine Exhaust

Substance (Common Name)	I.U.C Name	8-hour Time-weighted Exposure Limits, Except "C"* ppm	mg/m^3
Acetaldehyde	Ethanal	200	360
Acetone	2-Propanone	1000	2400
Acrolein	Propenal	0.1	0.25
1, 3-Butadiene	(Vinylethylene)	(1000)	(2200)
Lampblack	Amorphous Carbon		3.5
Carbon Dioxide	Carbon Dioxide	5000	9000
Carbon Monoxide	Carbon Monoxide	50	55
Crotonaldeyde	2-Butenal	2	6
Diazomethane	Azimethylene	0.2	0.4
Ethylbenzene	Ethylbenzene	100	435
Heptane (n-heptane)	Heptane	500	2000
Hexane (n-hexane)	Hexane	500	1800
Hexone	Hexone	100	410
Methylacetylene	Propyne	1000	1650
Methylcyclohexane	Methycyclohexane	500	2000
Nickel Carbonyl		0.001	0.007
Nitric Oxide	Nitric Oxide	25	30
Nitroethane	Nitroethane	100	310
Nitromethane	Nitromethane	100	250
*C-Nitrogen Dioxide	Nitrogen Peroxide	5	9
Octane	Octane	500	2350
Ozone	Ozone	0.1	0.2
Pentane	Pentane	1000	2950
2-Pentanone	Methyl-n-Propyl Ketone	200	700
Sulfur Dioxide	Sulfur Dioxide	5	13
m-Xylene (Xylol)	1,3-Dimethylbenzene	100	435

*Limits for substances preceeded by "C" are absolute permissible concentration exposure limits, regardless of time of exposure.

Table 2.3 b OSHA Acceptable Ceiling Concentrations for Substances Found in Diesel Engine Exhausts

				Acceptable Maximum Peak Above Acceptance Ceiling Concentration for an 8-hour Shift	
Material	I.U.C. Name	8-hour time Weighted Average	Acceptable Ceiling Concentration	Concentration	Maximum Duration
Benzene	Phene	10 ppm	25 ppm	50 ppm	10 Minutes
Formaldehyde	Methanal	3 ppm	5 ppm	10 ppm	30 Minutes
Toluene	Phenylmethane, Methylbenzene -	200 ppm	300 ppm	500 ppm	10 Minutes

Table 2.3 Federal Limits on Exposure to Contaminants (Cont.)

Notes to Tables 2.3a and 2.3b:

Except for the absolute permissable limits (identified by prefix "C"), the tables show the allowable limit of concentration for average exposure over an 8-hour workshift and a 40-hour work week for exposure to single toxic or hazardous substances. In the case of a combination of toxic or hazardous substances, summation of all of the fractions of the weighted average concentrations divided by the allowable concentrations shall not exceed unity. In illustration, assume the following were the only listed toxic or hazardous substances present and the human exposure was for a period of two hours per shift, but in a 6-day work week.

Substance	Concentration PPM	Allowable Concentration for Table (ppm)	Fraction
Acetaldehyde	10	200	0.05
Acrolein	0.01	0.1	0.10
Carbon Dioxide	1000	5000	0.20
Carbon Monoxide	10	50	0.20
Nitric Oxide	10	25	0.40
C-Nitrogen Dioxide	3	5	0.60
Ozone	0.03	0.1	0.30
Sulfur Dioxide	1.25	0.5	0.25
		Sum of Fractions	2.10

$$\text{Computation} = 2.10 \times \frac{2}{8}\ \frac{\text{hours}}{\text{hours}} = 0.525$$

$$0.525 \times \frac{6 \text{ days}}{5 \text{ days}} = 0.63$$

As 0.525 is less than unity, the exposure is below OSHA limits for a single shift (note that exposure for longer than 8 hours, as in continous exposure for a 12-hour shift would have resulted in a multiplier of 1.5 for the sum of fractional concentrations). As 0.63 is less than unity, exposure at this level for the entire 6-day work week is below OSHA limits. As the concentration of 3 ppm nitrogen dioxide (the only substance with a "C" prefix) does not exceed the maximum permissable concentration of 5 ppm, the instantaneous exposure limits are not exceeded. It is important to note that there are widely different concentration limits within chemical groupings (compare concentration limits for crotonaldehyde, acetaldehyde Table a , and formaldehyde Table b).

micrograms/m^3. The current maximum 24-hour limit for total suspended particulates (TSP) is 260 micrograms/m^3.

2.4 PRINCIPAL UNCERTAINTIES

There is no direct correspondence between observed emission levels shown in Appendix C (paragraph 4 of the Data Sheets) and concentration limits in Table 2.3, as additional factors are required for estimation of potential buildup of toxic or hazardous substances. The following additional factors would require consideration for a complete analysis:

- Life (persistency) of substances subject to oxidation or other chemical reaction in the environment

- Change in engine emissions as concentrations of emitted exhaust components rise in an enclosed area (e.g., potential increase in carbon monoxide production as carbon dioxide level in intake air increases)

- Time of operation of the engine

- Emissions produced over the engine work cycle (e.g., at no load and at fractional and full load)

- Volume of the enclosed environment

- Rate of air change of the enclosed environment and extent that the air change is uniform over the volume (especially for overhead ventilation and heavier-than-air toxic gases)

- Effective concentration of emissions (e.g., concentration of exhaust emissions when water vapor is separated by condensation and aerosols and other particles settle out of the air)

There are uncertainties in the use of the OSHA concentration limits for individual substances for the situation of combined toxic agents. These uncertainties may be of no greater magnitude than the basis for selecting the precisely stated limits shown in the table. However, there may be synergistic effects in exposure to combinations of some gases, as indicated in the following quote from reference 42: "Carbon monoxide is about 8 times more toxic in the presence of carbon dioxide and water vapor." Water vapor and carbon dioxide are major components of diesel engine exhaust and carbon monoxide is one of the principal toxic components of the exhaust. It might also be more appropriate to consider the concentrations of agents grouped by their physiological effects (e.g., nerve agents, asphyxiants, vomiting agents, etc.). Further, there is the question of treatment of substances which have been identified in diesel engine exhausts which are not on the OSHA list. Such substances may not have been considered; may have been recognized as toxic, but with no limit yet established; or may have been considered nontoxic. Different concentration limits have been established for many substances by different foreign regulating agencies (as can be noted in the data sheets at Appendix C). These differences are an order of magnitude in some cases. In some instances, limits have been established by foreign agencies for substances not included on the OSHA lists (e.g., for methane and ethane).

Recommendation of revisions to the OSHA lists is beyond the scope of this effort. It appears that there are additional diesel exhaust components which could be added to the lists and that there may be other research suggesting significantly lower concentration limits for some of those substances on the lists.

SECTION III
DIESEL ENGINE CHARACTERISTICS AND TESTING

3.1 DIESEL ENGINE FEATURES

The basic diesel engine involves a fluid fuel injected into air compressed in a cylinder to a level that its temperature is above the ignition temperature of the fuel, and converting the resulting energy to mechanical work by action on a piston. There are many variations on the configuration, operational cycles. and use of such engines. The typical principal subsystems are identified in Table 3.1. Sources for material in Section III includes references 46, 52, 53.

3.2 PHYSICAL PARAMETERS

Diesel engines may be classified and compared based on their physical features. These features include dimensions and design (e.g., selection among the subsystem design choices illustrated in Table 3.1). The principal physical parameters used for diesel engine identification are indicated in Table 3.2.

3.3 OPERATIONAL PARAMETERS

Diesel engine performance is measured by operational parameters. These are obviously dependent upon the physical parameters (Table 3.2), but are also dependent upon design features which are not included among typical physical comparisons. Two engines with the same displacement, compression ratios, type of fuel supply, governing, air supply, exhaust systems, etc., may still have widely varying design performances if, for example, one was designed for medium speed (1200 rpm or less) and the other had the lubrication, cooling capacity, and selection of engine alloys allowing sustained high-speed operation.

Engines may be designed for optimum performance in a given role (e.g., electric power generation) or with a given subsystem (e.g., naturally aspirated), but may be adapted for other applications such as variable speed vehicular usage, or for higher output, as in adding turbocharging and aftercooling. Usage in these other applications may extend the sales potential for a given engine line, but they may not be the same

Table 3.1. Typical Diesel Engine Sub-Systems

Subsystem	Typical Components	Typical Alternatives
Combustion Chamber (4-Stroke, 2-Stroke)	Cylinder	- Solid Walls - Valve Ports in Walls - Valves and Injector in Wall (opposed Pistons)
	Cylinder Head	- Open Combustion - Precombustion Chambers - Ante/Divided Combustion Chambers - Air-cell in Cylinder Head - Energy Cells - Turbulence Chambers
	Piston	- Flat Top - Swirl Design - Air-cell Design - Concave, Hollow, or Inset Combustion Chamber Design - Single Piston - Opposed Piston
	Fuel Injection System	- Air-injection - "Solid"-injection -- Common-rail -- Individual (jerk) Pump -- Unit-injector -- Distributor

Table 3.1. Typical Diesel Engine Sub-Systems (Cont.)

Subsystem	Typical Components	Typical Alternatives
Fuel Supply	Pump	- High-pressure Pump Feeding Common "Rail" (Manifold) - Individual (piston) Pumps - High-pressure Distributor - Low-pressure Pump Feeding Mechanically-driven Nozzles
	Injectors	- Pump Pressure Activated Spray Nozzle - Mechanically Activated Fuel Injector
Air Supply	Air Cleaner	- Air Filter - Cyclonic Air Cleaner
	Super Charger	- Turbocharger (Exhaust Gas Driven) - Engine-driven Blower - Separately-powered Blower
	Aftercooler (note: indicated definitions of "aftercooler" and "intercooler" are not rigorously distinguished by manufacturers)	- "Aftercooler" (cooled with engine coolant as element of engine cooling system) - "Intercooler" (cooled by separate water sources, generally stationary and marine engine applications).
Cooling	Liquid Cooling System (Mobile Application)	- Fluid Pump - Heat Exchanger (Radiator) - Fan/Blower
	Air Cooling System	- Fins - Ducts - Fan/Blower

Table 3.1. Typical Diesel Engine Sub-Systems (Cont.)

Subsystem	Typical Components	Typical Alternatives
Exhaust	Turbocharger	- Turbocharger
	Exhaust Silencer	- Baffle Chamber - Filter Type
	Spark Arrester	- Spark Arresting Filter - Combined with Silencer
	Purifier	- Catalytic Purifiers
Starting	Starter Motor	- Electric Motor Driven - Compressed Air Motor Driven - Internal Combustion *Gasoline* Starting Engine - Compressed Air Admission
Governing	Manual Controls	- Hand or Foot Throttles
	Speed Governors (Variable Speed, Speed-Limiting, Load-Limiting Isochronous)	- Mechanical - Hydraulic -- Speed Droop -- Permanent Speed Droop -- Isochronous - Electronic -- Speed Sensing -- Load Sensing

Table 3.2. Physical Parameters Used in Diesel Engine Descriptions

Parameter	Typical Units
Displacement	cc, cu. in.
Compression Ratio	Dimensionless
Stroke	mm, in.
Bore (cylinder diameter)	mm, in.
No. of Cylinders	units
Cycles	Number of strokes
Valve Positions	In head, overhead
Cylinder Configuration	In-line, Horizontally opposed, etc.
No. of Valves (per cylinder) (intake and exhaust)	units
Piston Surface Configuration	Word description (e.g., flat, hollow, chambered, etc.)
Cylinder Configuration	Word description (e.g., open turbulence, precombustion, divided combustion, ante chambers; air, energy cells; Lanova, Ramsey energy cells,
Injection Mechanism (Governor Generally Integral with Distributor Pump)	Word description of injectors, pumps, actuation, and governing system (e.g., spray nozzles, injectors, unit injectors, individual pumps, etc. See Table 3.1)
Rotational Moment of Inertia (less flywheel)	Kg-cm^2, slug-ft^2
Cooling System	cooling medium (water, air)
(NOTE: Most of following parameters may be tailored for the application.)	
Liquid Cooling System Capacity	Liters, gallons/quarts
Governor	Word description of type (e.g., mechanical, hydraulic, etc. See Table 3.1)

Table 3.2. Physical Parameters Used in Diesel Engine Descriptions (Cont.)

Parameter	Typical Units
Flywheel	Physical dimensions or rotational moment of inertia
Turbocharging	Number of turbochargers
Supercharging	Existence (compression ratio, outlet air pressure, etc.) Type (e.g., turbocharging, engine driven)
Aftercooling (if supercharged)	Existence
Intercooling (if supercharged)	Existence (Max. input water temp.)
Exhaust Conditioning	Type (e.g., silencer, spark arrester, catalytic converter, etc.)
Fuel Tank Capacity	Liters, gallons
Day Tank Capacity	Liters, gallons
Fuel Treatment	Word description (e.g., filter, water separator, automatic water separator, etc.)
Air Treatment	Existence and word description of type (e.g., filter, dry-type filter, cyclonic dust separator, etc.)
Oil Capacity	Liters, gallons/quarts
Oil Cooling	Word description of type (e.g., finned air-flow radiator, fluid heat exchanger, etc.)
Oil Treatment	Existence and word description of type filter (e.g., replaceable element, type of element, etc.)
Starting System	Word description (e.g., type starting motor, compressed air admission)
Starting Motor	Identification of actuating power (e.g., electric motor, compressed air motor, gasoline engine)

Table 3.2. Physical Parameters Used in Diesel Engine Descriptions (Cont.)

Parameter	Typical Units
Electric Generation	Identification of type generation (alternator, generator) voltage, and amps or watts
Electric Storage	Battery storage capacity (e.g., amp-hours, cold cranking duration time in minutes)
Special Cold Weather Starting/Operating Features	Identification (e.g., either addition to intake air, fuel heating, combustion chamber pre-heat with low compression ratio cranking mode)
*Dimensions (length, width, height)	mm, in.
*Weight	kg, lbs.

*Configuration or components included must be known for comparisons of dimensions and weights

configurations or mix of design parameters as an engine initially designed for that specific end use. Operational performance in the role would be the desired measure for comparison of candidate engines for equipment design. In the (usual) absence of comprehensive data permitting comparisons in the exact role, operational characteristics which most closely approach the anticipated requirements are used for engine selection.

Table 3.3 identifies many operational parameters of an engine. Most of these require standardized testing or definitions to permit true comparison between candidate engines. Some of the operational features of an engine which are of major concern (e.g., mean time between failure and fuel economy over an actual work cycle) are generally not available or are subject to varied interpretations. Tests are incorporated in Government development and/or procurement contracts which are intended to establish and provide the basis for improving certain operational features (e.g., mean time between overhauls) and other generally subjective standards, such as maintainability and repairability. Most engines have not undergone such testing and those which have had such testing generally received it in conjunction with tests on a powered piece of equipment, with the result that data on the engine alone is further subject to widely varying interpretations.

3.4 EMISSIONS OTHER THAN EXHAUST

The principal environmental effects of diesel engine operation are the exhaust, engine heat dissipated by the engine cooling systems, engine heat dissipated by radiation from heated surfaces (other than the cooling system radiators), noise of operation, noise emitted or produced by the exhaust system, and gaseous emissions due to crankcase ventilation. The magnitude of emissions other than the composition and heat content of the exhaust gases and the heat output of the cooling system vary widely with engine configuration and with the inclusion of measures to reduce them. Thus, noise can range from levels in excess of allowable limits without ear protection, to relative quiet (as with diesel engines powering luxury automobiles). Crankcase fumes can be included in the intake air and combusted within the engine. Heat radiation from engine surfaces and noise can be intercepted by the engine enclosure.

Table 3.3. Operational Parameters for Diesel Engines

Feature	Typical Units
Maximum Continuous Work Output	kW, BHP at specific RPM with stated limits on max. ambient air temperature (°C, °F) and elevation above sea level (M, ft)
(Note: unstated ("assumed") conditions for other parameters are usually at maximum continuous output)	
Maximum Transient or Intermittent Work Output	kW, BHP at specific RPM with stated conditions and time (may indicate temperature rise in °C, °F)
Mechanical Efficiency	% (BHP over "indicated" horsepower)
Maximum Continuous Work Output at a Range of Engine Speeds.	kW, BHP at selected RPM (or graphical depiction) with stated conditions
Maximum Torque (not independent of RPM and Output)	N-m, lb-ft. at specific RPM
Fuel Consumption	Liters/hour, Liters/kWh, Kg/hour, Kg/kWh, gal/hour, or lbs/BHP-hr (of specific grade fuel, usually No. 2 diesel), at standard conditions of temperature and altitude, with engine at specific speeds (RPM) and work output levels (may be presented graphically)
Brake Thermal Efficiency	% (work output over energy in fuel)
Brake Specific Fuel Consumption (BSFC)	lbs/BHP-hr
Oil Consumption	Kg or Liters per unit of time (lbs or gals/qts per time unit) at assumed RPM and output
Brake Mean Effective Pressure (BMEP)	bar, kilopascals, psi at assumed RPM and work output

Table 3.3. Operational Parameters for Diesel Engines (Cont.)

Feature	Typical Units
Exhaust Temperature Leaving Cylinder	^{o}C, ^{o}F at assumed conditions of RPM and output
Exhaust Temperature Leaving Exhaust System	^{o}C, ^{o}F at assumed conditions of RPM and output
Volume of Exhaust Gas	Liters, cu. ft per unit of time under assumed conditions
Exhaust Backpressure (at cylinder exhaust)	kilopascals, psi under assumed conditions
Intake Air Requirement	Liters, cu. ft. per unit of time under assumed conditions
Volumetric Efficiency	% (of volume admitted at std. temp., pressure, engine operation over piston displacement)
Vibration Spectrum	Magnitude of acceleration (G) over spectrum of frequencies (Hz) at assumed or specified conditions
Liquid Cooling System Flow Rate	Liters/min., gals/min. at assumed RPM
Cooling System Heat Discharge Rate	Calories/min., BTU/min. at assumed RPM and work output
Oil Cooling System Heat Discharge Rate	Calories/min., BTU/min. at assumed RPM and work output
Aftercooler or Intercooler Heat Exchange Rate	Calories/min. BTU/min. at assumed RPM and work output
Governor Performance	Recovery time and droop (%) based on work output and % load variations (may be in RPM or specific output parameters, e.g., voltage for electric generation applications)
Mean Time Between Failure (MTBF)	Hours (between defined "failures" for operation at assumed/specified work cycles)

Table 3.3. Operational Parameters for Diesel Engines (Cont.)

Feature	Typical Units
Mean Time Between Overhauls (MTBO)	Hours (between defined levels of required repair and maintenance operations)
Mean Time to Repair (MTTR)	Hours (to accomplish average repair causing a "failure")

Heat is the principal emission other than exhaust gas. Typically (and varying widely with engine design and conditions of operation), one-third of the heat produced by the fuel is converted to brake horsepower, ten percent is expended in overcoming engine friction, and the residual is dissipated roughly equally between heat in the exhaust gases, and heat removed by the cooling system and radiation.

3.5 EXHAUST EMISSIONS

Substances which have been identified in diesel engine exhaust are listed in Table 2.1. Data sheets for most of these substances are included at Appendix C. Measurements of the concentration levels of the substances in the exhaust vary widely. Ranges of concentrations which have been noted are indicated in Table 3.4. References for these observations are identified on the corresponding data sheets for the substances at Appendix C. Data on observed concentrations of the largest components of diesel exhaust have not been identified in the test literature, specifically: nitrogen, oxygen, and water. A distribution of diesel exhaust components totaling 100% has therefore not been attempted in this report. However, such a distribution would be input to analysis of potential secondary chemical reactions, assessments of the effective concentrations following condensation and separation of excess water vapor, and prediction of the impact of the exhaust on the long-term composition of the air (etc.) within a closed volume.

3.6 DATA COLLECTION

A variety of test procedures are employed to measure diesel engine performance and to identify and quantify constituents of diesel-engine exhaust. The Society of Automotive Engineers (SAE) is the principal American publisher of standardized procedures relating to diesel engine performance and emissions. In addition, standardized tests have been established by the American Society for Testing and Materials (ASTM), Deutches Industrie Norm (DIN), British Standards, International Standards Organization (ISO), and other industrial, professional, and governmental agencies.

The principal test procedure relating to standardized emissions testing is the U.S. Environmental Protection Agency 13-Mode Test for stationary engines for the

Table 3.4. Concentrations of Substances Identified in Diesel Engine Exhaust
(Extracted from Data Sheets at Appendix C)

Substance (Common Name)	**IUC Name	**Observed Range of Concentration
Acetaldehyde	Ethanal	3.2 ppm, 35-777 mg/m^3, 2-88 $\mu g/m^3$
Acetone	2-Propanone	25-200 $\mu g/m^3$, 459-1164 mg/m^3
Acetylene	Ethyne	0.3-7.0 ppm, 14.1% of HC
Acrolein	Propenal	4 ppm, 10 mg/mi
*Anthanthrene	--	--
*Benz(a) anthracene	--	--
Benzaldehyde	Benzenecarbonal	0.3 ppm, 177-706 mg/m^3
Benzene	Phene	0.3-1.0 ppm, 2000 $\mu g/m^3$, 2.4% of HC
*Benzo (ghl)perylene	--	--
*Benzopyrene	Benzo-Alpha Pyrene (BaP)	--
1,3-Butadiene	Vinylethylene	2.0 ppm, 8 $\mu g/m^3$
Butane	Butane	5.3% of HC
α-Butylene	1-Butene	2 ppm, 1.8% of HC
β-Butylene	(trans) 2-Butene	0.6% of HC
Butyraldehyde	1-Butanal	0.3 ppm
Caproaldehyde	Hexanal	0.2 ppm, 0-1589 mg/m^3
Carbon Dioxide	Carbon Dioxide	1.5 - 17%
Carbon Monoxide	Carbon Monoxide	12.2-2000 ppm, lg/m, 76-7842 mg/m^3
*Chrysene	1, 2-Benzophenanthrene	--
Crotonaldehyde	(trans) 2-Butenal	1-18 $\mu g/m^3$
*Cyclopentano (c,d) pyrene	--	--

Table 3.4. Concentrations of Substances Identified in Diesel Engine Exhaust (Continued)
(Extracted from Data Sheets at Appendix C)

Substance (Common Name)	IUC Name	Observed Range of Concentration
Diazomethane	Azimethylene	30 $\mu g/m^3$
*Dibenz (a,h) anthracene	--	--
*Dibenzopyrene	--	--
2, 3-Dimethlybutane	2, 3-Dimethylbutane	0.5% of HC
2, 3-Dimethylpentane	2, 3-Dimethylpentane	0.9% of HC
2, 4-Dimethylpentane	2, 4-Dimethylpentane	0.3% of HC
Ethane	Ethane	0.5-1.3 ppm, 1.8% of HC
Ethylbenzene	Ethylbenzene	0.7% of HC
Ethylene	Ethene	9-26.1 ppm, 43 mg/mi, 14.5% of HC
p-Ethyltoluene	1-Ethyl-4-Methylbenzene	0.7% of HC
Formaldehyde	Methanal	12-18.3 ppm, 20 mg/mi, 2118-3071 mg/m^3
Heptane	Heptane	5 $\mu g/m^3$
Hexane	Hexane	643 $\mu g/m^3$, 1.2% of HC
Isobutanal	2-Methylpropanal	318-1659 mg/m^3
Isobutane	2-Methylpropane	0.8% of HC
Isooctane	2, 2, 4-Trimethylpentane	1.0% of HC
Isopentane	2-Methylbutane	3.7% of HC
*Lampblack	Amorphous Carbon	--

Table 3.4. Concentrations of Substances Identified in Diesel Engine Exhaust (Continued)
(Extracted from Data Sheets at Appendix C)

Substance (Common Name)	IUC Name	Observed Range of Concentration
Mesitylene	1, 3, 5-Trimethylbenzene	0.4% of HC
Methane (Marsh Gas)	Methane	0.5-7.7 ppm, 13 mg/mi, 16.7% of HC
Methylacetylene	Propyne	0.9% of HC
Methylcyclohexane	Methylcyclohexane	2-100 $\mu g/m^3$
Methyl Isobutyl Ketone	Hexone	402 $\mu g/m^3$
2-Methylpentane	2-Methylpentane	1.5% of HC
*Nickel Carbonyl	--	--
Nitric Oxide	Nitric Oxide	3.8-1500 ppm
Nitroethane	Nitroethane	3-6 7 $\mu g/m^3$
Nitromethane	Nitromethane	20 $\mu g/m^3$
*Nitrogen	Nitrogen	--
Nitrogen Dioxide	Nitrogen Dioxide	2.9 ppm
Octane	Octane	5-800 $\mu g/m^3$
*Oxygen	Oxygen	--
*Ozone (Secondary Product)	Ozone	--
*Peroxyacetylnitrate (PAN) (Secondary Product)		--
Pentane	Pentane	256 $\mu g/m^3$, 2.5% of HC
2-Pentanone	Methyl-n-Propyl Ketone	84 $\mu g/m^3$

Table 3.4. Concentrations of Substances Identified in Diesel Engine Exhaust (Continued)
(Extracted from Data Sheets at Appendix C)

Substance (Common Name)	IUC Name	Observed Range of Concentration
*β-Propialactone	β-Propialactone	--
Propylene	Propene	0.5-15.1 ppm, 14 mg/mi, 6.3% of HC
*Steam	--	--
Sulfur Dioxide	Sulfur Dioxide	1 ppm, 7.26-222.3 g/hr
Toluene	Phenylmethane, Methylbenzene	0.1-1.0 ppm, 4100 $\mu g/m^3$, 3.1% of HC
1, 2, 4-Trimethylbenzene	1, 2, 4-Trimethylbenzene	0.4% of HC
*Water (Vapor, Aerosol)	--	--
m-Xylene	1, 3-Dimethylbenzene	30-5500 $\mu g/m^3$, 1.9% of HC

*No data sheet at Appendix C.
**Blank entries indicate IUC name not identified, concentration values not identified.

measurement of hydrocarbons, carbon monoxide, and nitrogen oxides in exhausts. Appendix D presents test description references relating to engine exhaust testing and/or the sampling, identification, and quantification of gaseous substances as found in diesel engine exhausts.

SECTION IV
REDUCED EMISSION/CLEAN BURNING TECHNOLOGY

4.1 BACKGROUND

Today's RE/CBDE technology is a re-emergence of diesel technology which was in use half a century ago. Precombustion chamber (PCC) diesel engines were then in common use, principally to lower the broke mean effective pressure (BMEP) and provide a smooth, long-lasting flame front. These engine design characteristics were required to allow use of cast iron pistons and other lesser-quality, lower-strength materials throughout the engine. The early PCC engines had good low-speed torque characteristics and could use lower-quality fuels than open combustion chamber engines. They also possessed high specific fuel consumption compared to later standards, but this could be offset by lower production cost and/or lesser maintenance and repair associated with the lower BMEP over diesel engines which did not have PCC design. Low BMEP engines by definition have lower power at the same RPM than engines with higher BMEP and identical displacement. The early PCC engines also emitted lower levels of emissions than some of today's engines, but this was not a consideration in their use. The associated higher emission levels were also not a consideration in the adoption of higher BMEP, fuel-efficient, open combustion chamber engines.

Around the middle of the 20th century, a high-speed, 2-cycle diesel engine using direct fuel injection emerged with high horsepower to weight and low volume to weight characteristics. This engine was also supercharged and was considered high speed. It undoubtedly emitted large quantities of hydrocarbons. This supercharged, high speed, directly injected diesel engine used advanced metal alloys for moving parts and wear surfaces in the engine.

In the mid-1950s, the direct-injection, open-chamber, 4-cycle diesel engine became more and more popular due to its fuel economy (a roughly ten percent improvement compared to the PCC engines). In the 1960s, turbochargers were added to the larger diesels. The most common large diesel engines today are of the 4-cycle, high compression ratio, open-chamber design. The greatest output from a given basic

engine configuration is obtained with the addition of exhaust-gas-driven supercharging of intake air (turbocharging) and cooling the compressed intake air prior to its use i the engine ("aftercooling" if accomplished with the engine cooling system, "intercooling" if accomplished with a separate cold water source). "Intercooling" permits maximum engine performance due to the lower temperatures achievable and the resulting maximum mass of oxygen in the cylinder charge.

The 1960s saw greatly increased concern for the environment and for the health of people who worked in closed environments (such as coal mines). This has brought renewed interest in the PCC engine, which offers the advantage of relatively lower toxic emissions. Both the military and civilian sectors are, to one degree or another, in the dichotomous position of trading fuel consumption (and many other costs) against emissions. In an open operational environment, the fuel cost and environment are traded off in social value by fiat of the Environmental Protection Agency (EPA), the Congress, and the individual states.

The background research for this report revealed no documented long-term physical impact to humans from diesel exhaust per se. There is however a consensus that diesel exhaust is "bad." As shown in Section II and Appendices B and C, it is known that diesel exhaust contains compounds considered or proved to be toxic, irritating, and/or carcinogenic in isolation, and that there may be severe synergistic effects associated with concurrent exposure to some of the exhaust constituents.

The Army has identified a need to use diesel engines in CSC environments. Use of a low emission engine in such applications appears appropriate. The physiological bases for exactly what emission levels would be acceptable in such environments have not been determined, and there appears to be little evidence that such bases will be developed for such complex atmospheres in the near term under current programs.

Other technologies relating to improved fuel or power efficiencies are the adiabatic and the hypobar engines. The adiabatics have ceramic piston heads and ports to decrease the heat loss through the internal vital portions of the engine. No adiabatic engines are known to be commercially operational at this time. The hypobar

engines are provided with super turbocharging and experience high BMEPs which provide a high HP-to-weight ratio. Hypobar engines are operational in Europe, principally in France. Adiabatic, hypobar, and after-cooled engines are not known to provide lower emission characteristics.

Other automotive-type engines in development at this time are the turbine and the Wankel (rotary) engines. It is believed that neither of these engines will have enhanced emission quality, due to their increased specific fuel consumption and air flow. Data were requested only for conventional diesel engines and not for the above derivative diesels or other types of engines.

4.2 EFFECTS OF SPECIAL FEATURES

There are several features which have been added to heavy duty diesel engines in the past two decades which improve their operating efficiency.

4.2.1 Turbocharging

Exhaust driven turbochargers compress the intake air so that more air enters the cylinders (some engines may use belt-driven superchargers). The turbochargers remove energy from the exhaust and thus lower the exhaust temperature, which can be an advantage in a military infrared environment. More air in the cylinders increases the BMEP and temperature so that a more efficient energy conversion takes place. This follows the engineering axiom that "the higher the temperature of the working fluid, the more efficient the energy conversion." The increased BMEPs require more robust engine parts or result in a shorter engine life. The turbochargers operate at about 40,000 RPM in the heavy duty diesels, while automotive turbochargers may operate at up to 80,000 RPM. The high-frequency sound produced by turbochargers has an unknown effect on humans.

4.2.2 Direct Injection - Multiple Nozzles

The direct injectors place the fuel in the cylinder at the time that the compressed air is hot enough to initiate combustion in the open cylinder. The

compression ratios of the direct-injection, open combustion chamber engines are in the 20:1 to 22:1 range, causing high compression temperatures. This high temperature burning process is fuel efficient but not reduced-emission efficient. The injectors typically have four very fine nozzles vice single, large nozzles.

4.2.3 Precombustion Chambers (PCC)

The ignition in PCCs occurs in a small chamber in the cylinder head and progresses more evenly into the cylinders. The PCC engines generally use lower compression ratios to control the point of ignition and allow a more even flame front. The power is smoother and the emissions are cleaner due to the lower temperatures in the cylinder, but the fuel efficiency is decreased since the pressure rise due to combustion occuring on the downstroke only acts over the lower part of the downstroke.

4.2.4 Swirl Chamber

Swirl chamber combustion design for the cylinder creates a high turbulence facilitating a smoother burning process at lower compression ratios. Swirl design is enhanced through research of the combustion process using lasers and quartz windows in the cylinder head. The Ricardo, designed in England, is a forerunner in swirl chamber designs. This design, termed the "high-swirl" chamber in this study, provides a PCC-like combustion process. The effectiveness of the design is illustrated by the high ranking achieved by "high-swirl" engines in the comparative utility analysis (Section VI).

4.2.5 Engine Noise Levels

Engines in the horsepower range of concern to this study (35-80 BHP) produce noise levels in the 95-105 dB range. Some automotive design techniques are providing slightly lower noise levels, but most manufacturers are providing noise insulation kits for the engines which reduce the noise level about 10 dB at a cost of about $400 per engine. The maximum desired noise level of 85 dB (noise level limit without hearing protection, reference (60) is not met by most engines even with noise insulation packages.

4.2.6 Automated Controls

Electronic controls are being added or considered for diesel engines to improve their performance characteristics. There are injectors which are controlled by processors to vary the time and duration of fuel flow. The processor adjusts timing in response to such sensed variables as temperature and pressure (including altitude), humidity, and load conditions.

Another electronically controlled device under development (principally for automotive applications) matches the torque converter and automatic transmissions to the engine and load conditions. The processor-controlled automatic transmission system provides greater operating efficiency.

4.2.7 Summary

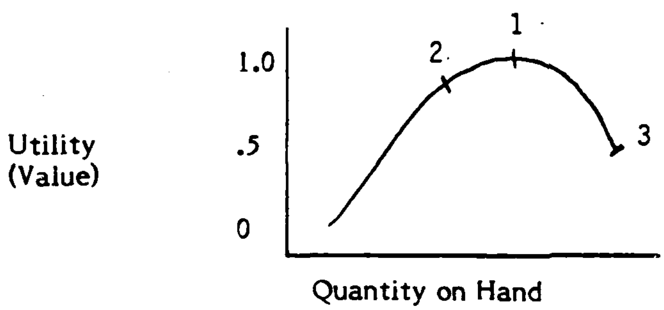
The most important single engine characteristic impacting the RE/CBDE is the combustion chamber design. The PCC and the high-swirl chambers appear to provide the lowest emissions on a competitive basis. The other features discussed provide improved operating efficiencies. Turbocharging of an engine designed for natural aspiration may increase emissions, since it increases the combustion chamber temperature and hence the undesirable emissions. No consideration was given to other derivative diesel engines such as adiabatics or hypobars since they are not available in the current time period. Rotary and turbine engines were considered beyond the scope of this effort. They are probably unsuited for serious consideration in MHE applications due to their inherently high fuel consumption and greater procurement and life cycle cost.

SECTION V
EVALUATION ALGORITHM

5.1 EVALUATION OF DATA

The evaluation of engine data comprised a combination of two evaluation techniques. The first technique involved the determination of variables that are important to the Army operational environment with emphasis upon the integration of a RE/CBDE for MHE. Once the variables were selected, they were judgmentally weighted based upon their value for the CSC environment. The second technique used in the evaluation analysis was the "utility theory." The utility theory provides a means for quantitatively assessing the relative merit of data points within each of the selected variables. It also provides a mechanism to deal with non-linear or curvilinear relationships between a data variable and its usefulness or utility to a customer. The measurement of utility is generally portrayed ranging from zero to one, as illustrated in the example for stockage of items of supply shown below:

Example Utility Curve for an Item of Supply



If the item of supply is a repair part required to maintain production, considerations in determining utility could include the importance of not running out of the item, advantage of economic order quantities, reorder and delivery times, and the investment and storage expenses of stockage. Point 1 on the curve represents the optimum stockage level. The utility curve could be used to set a reorder point (e.g., point 2) and requisitioning objective (e.g., point 3) such that the average stockage is at approximately the optimum level.

In reviewing potentially meaningful variables, establishing their relative importance (weighting the variables), and developing utility curves for RE/CBDEs, the primary concern for the operational environments relates to engine emissions. Toxic emissions are not desired. Pragmatically it is not feasible for diesel engines to produce none of the regulated emissions (CO, NO_x, and HC). There is also insufficient basis (as discussed at 2.4) to justify a complex curvilinear relationship for the utility function for any of the emissions. As a result, a linear negatively sloping line was selected as the utility curve for each of the selected variables. In accordance with this approach, utility increases as emissions decrease. The line was positioned so that the median of the data points (representing characteristics of candidate engines) rested in the utility region of .7 (the utility axis is typically established with values generally between 0 and 1). The upper-end utility was established at approximately 1.0 while the lower end was established at a utility of about .4. Similiarly, fuel consumption and the BHP to displacement ratio were selected as important variables and utility curves were established.

The utility curves (lines) for the selected variables are depicted in Figures 5.1 to 5.5. Each figure contains the equation for the utility curve (line). One reason for adoption of the utility theory methodology at the outset of the evaluation analysis was a presumed non-linearity in the relationship between the measurable variables and their utility. As it was determined that there were insufficient bases to establish quantitative non-linear utility curves, some of the capabilities of the utility approach are not used. However, the utility relationships at Figures 5.1 through 5.5 do provide for objective ranking of the candidate engines in each of the selected variables. The form of the utility lines was established, and accepted by the sponsor, prior to any data reduction. Approval of all utilities prior to analysis was considered necessary to avoid any bias in forming the utilities.

5.2 SELECTION OF VARIABLES

The obvious principal considerations in the evaluation of reduced emission/clean-burning diesel engines for use in material-handling equipment in closed and semi-closed environments are the levels of undesirable emissions and the engines' ability to

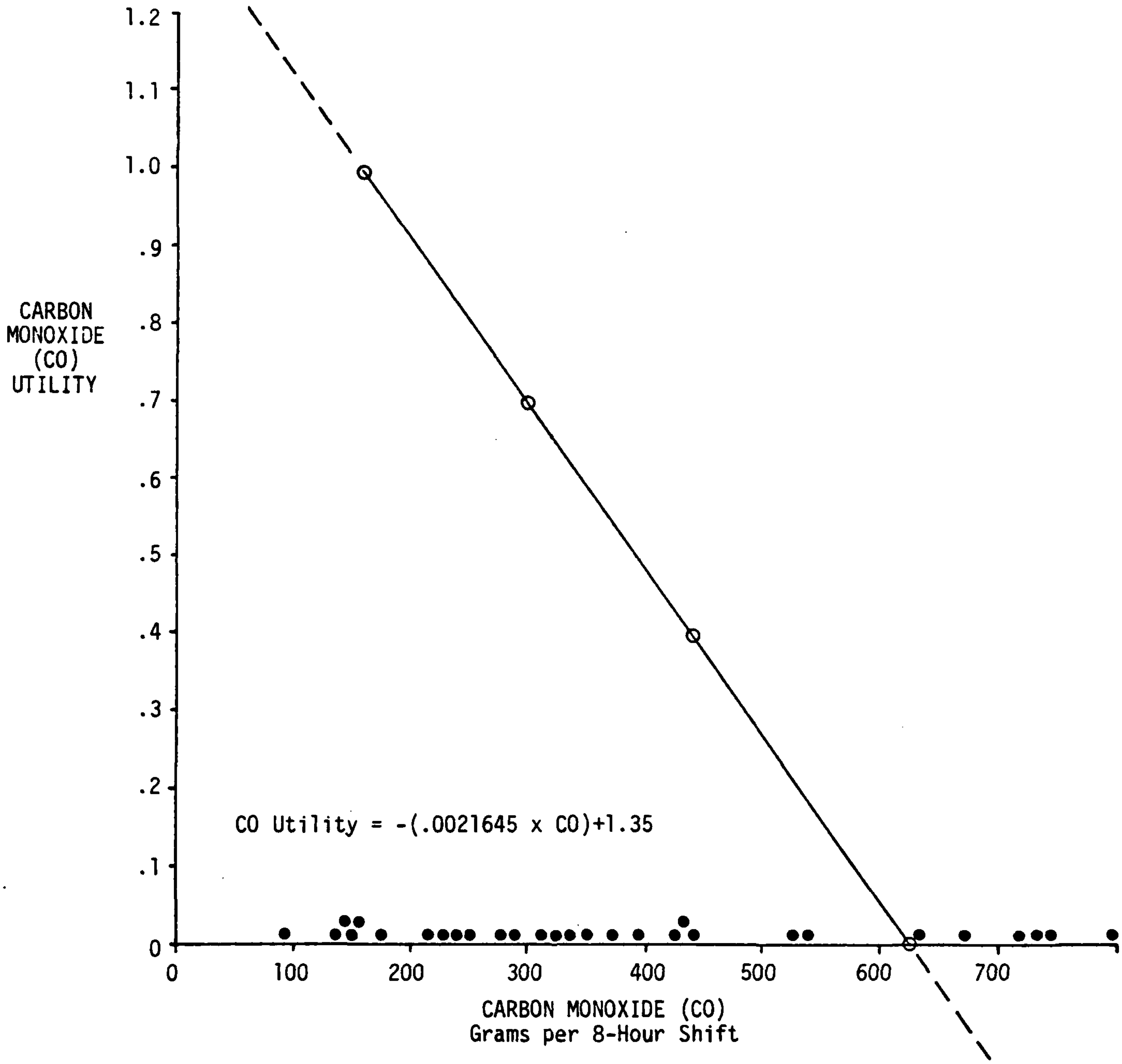


Figure 5.1 Carbon Monoxide Utility

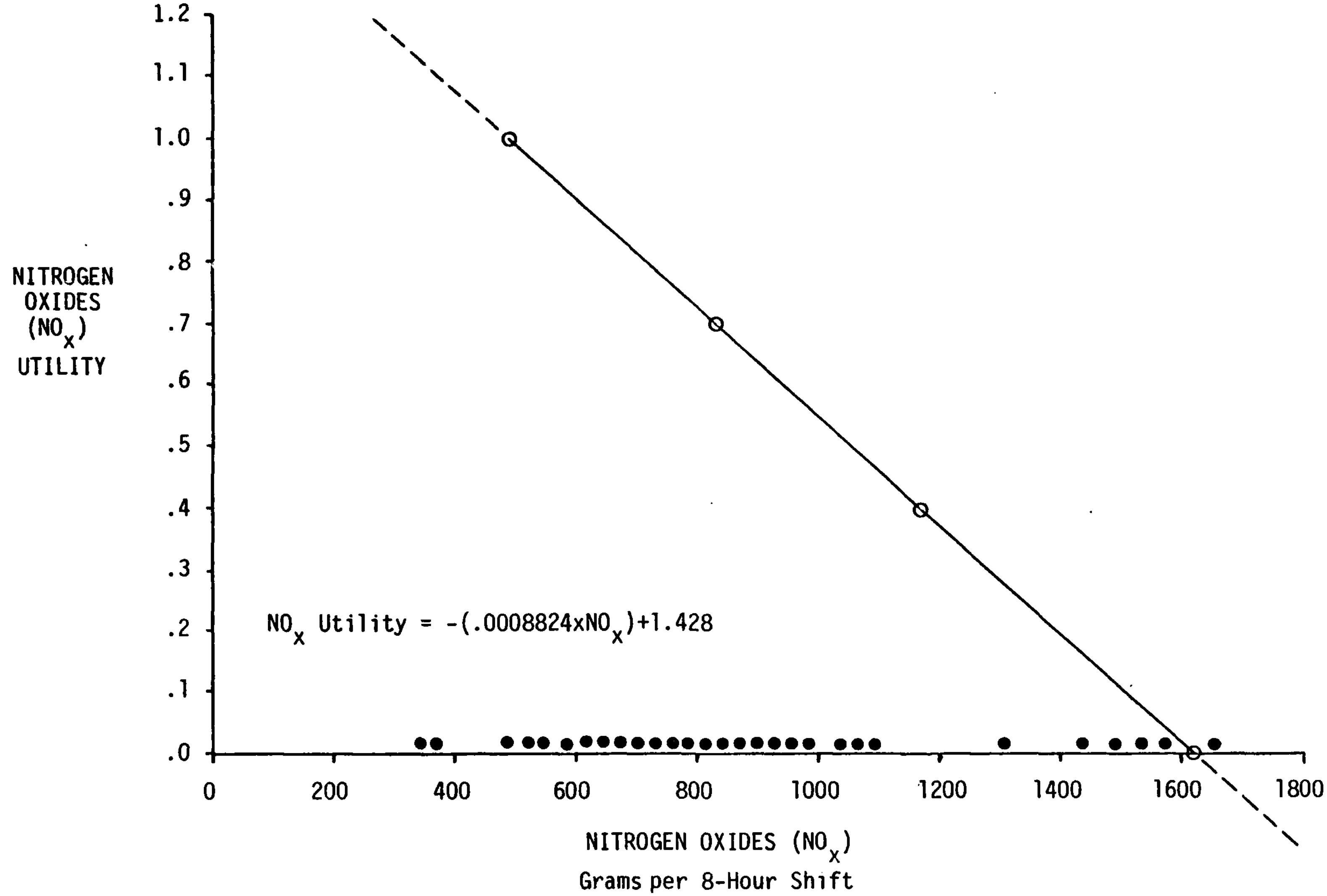


Figure 5.2 Nitrogen Oxides Utility

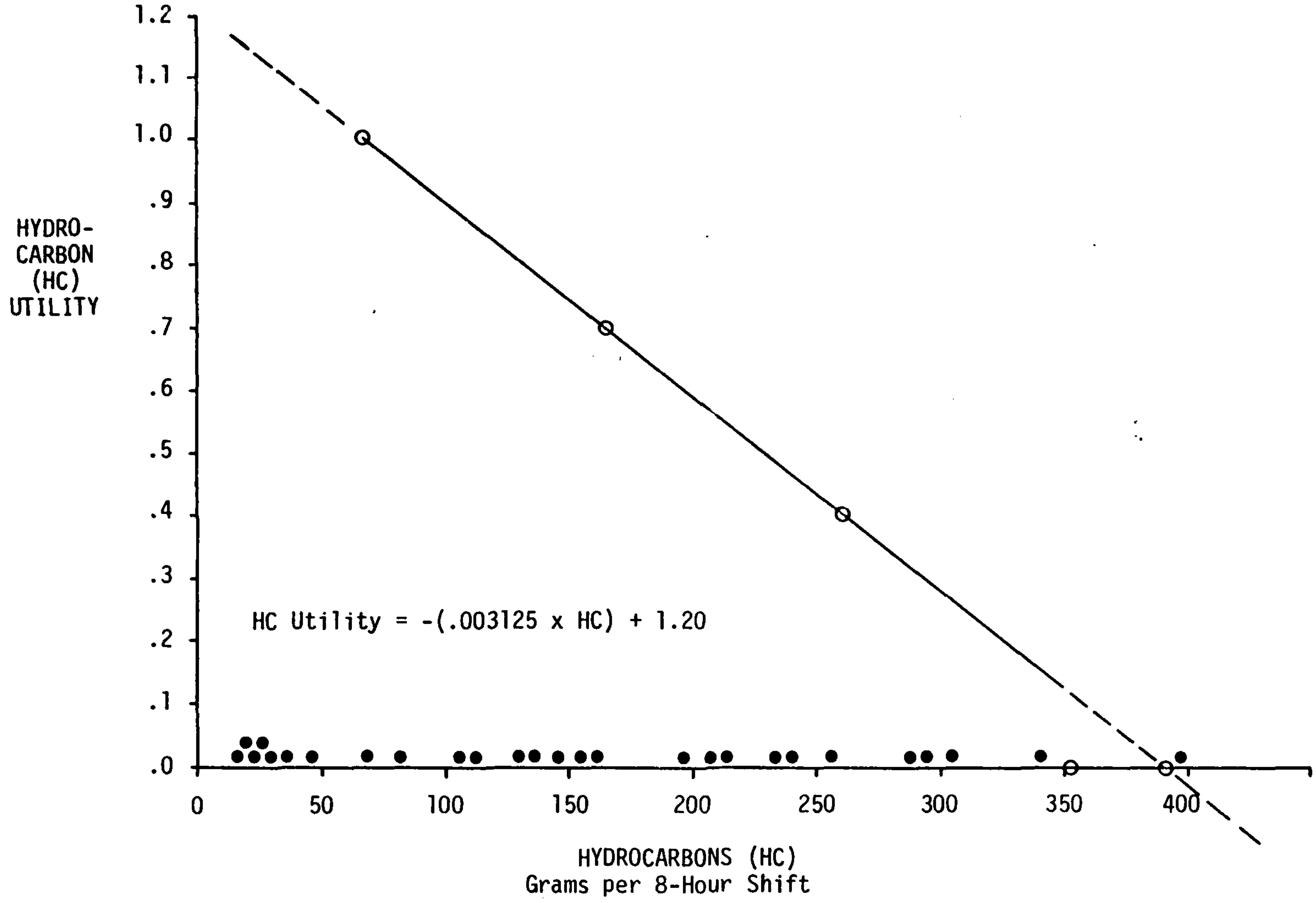


Figure 5.3 Hydrocarbon Utility

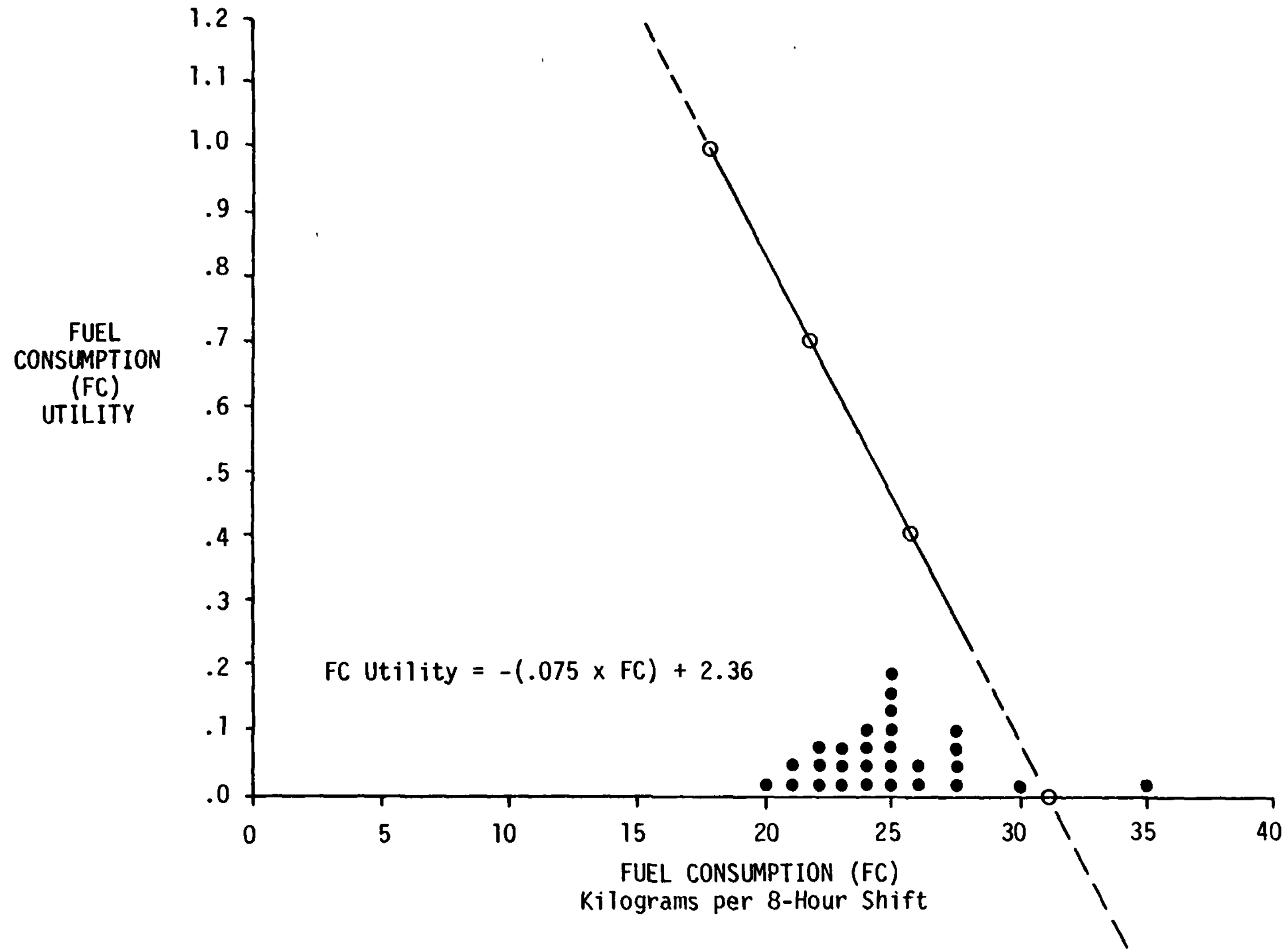


Figure 5.4 Fuel Consumption Utility

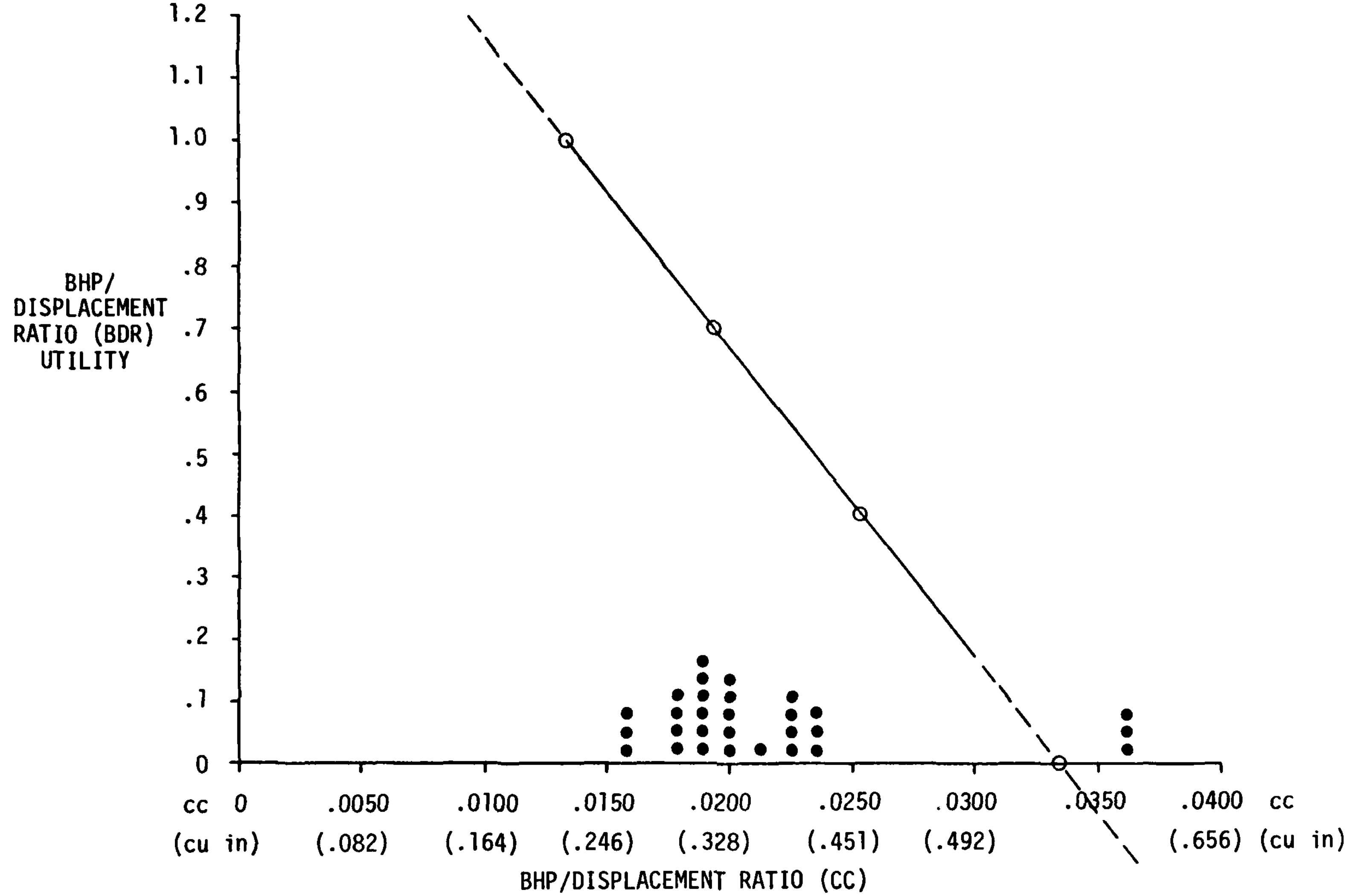


Figure 5.5 BHP/Displacement Ratio Utility

perform the tasks. Variables to be used in the comparative evaluation of the engines must therefore reflect these considerations.

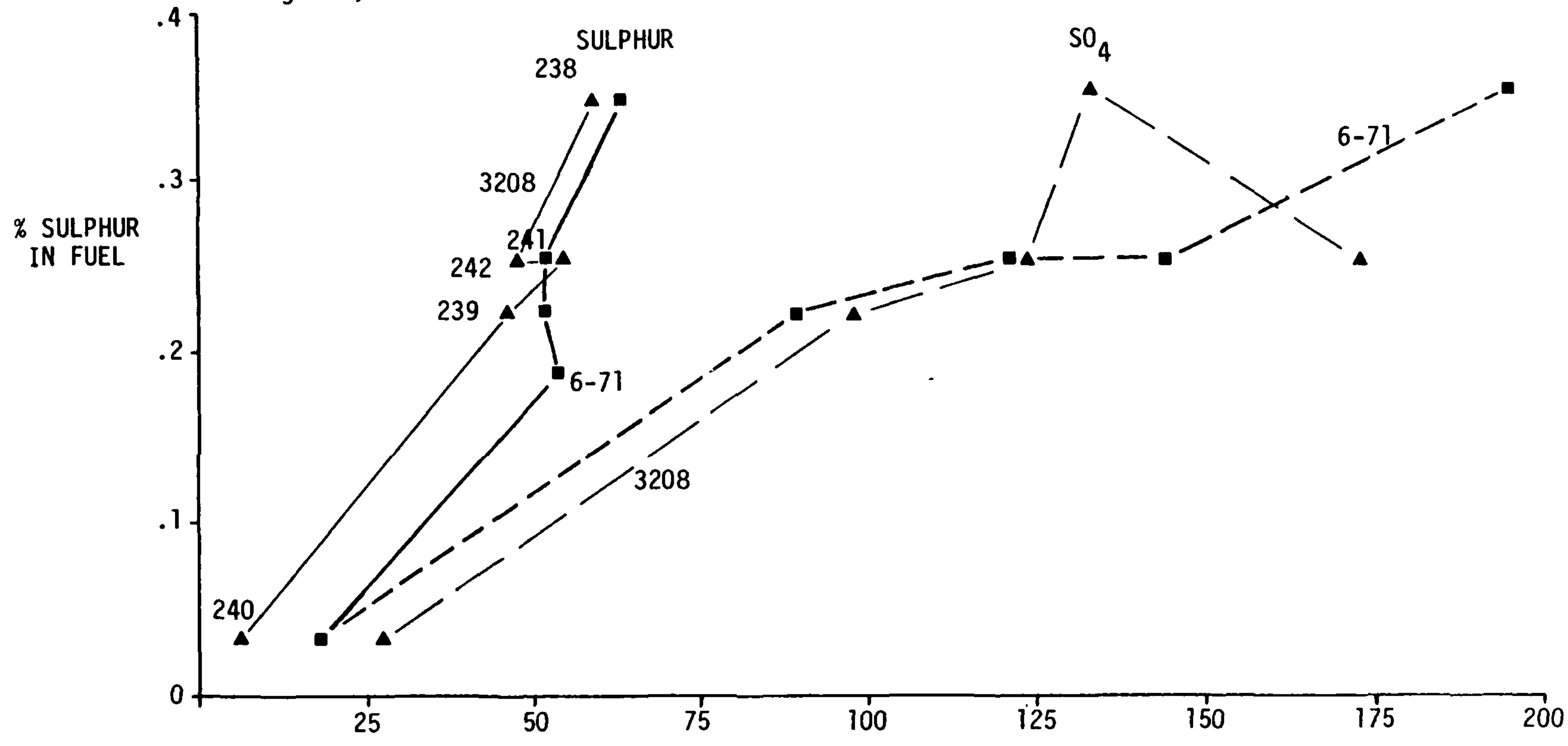
5.2.1 Engine Emission Utility Variables

The review of diesel engine emissions (Section II) determined that a large number of compounds have been found in diesel exhaust (Table 2.1). Most of these have been classified as toxic or hazardous; however, regulations directly affecting engines have generally only addressed gross measurement of carbon monoxide (CO), the nitrides of oxygen (NO_x), and hydrocarbons taken as a group (HC). The particulate content of diesel engine exhaust is to be measured, starting in 1986, for which a proposed standard is published in the Code of Federal Regulations (CFR) 86. The level of particulates was considered as an evaluation variable, but was not used as none of the manufacturers returned particulate data. Data were returned for levels of CO, NO_x, and HC, which were used as three of the utility variables.

Additional emission components of concern found in diesel exhaust are SO_4, SO_2, and sulphur. The sulphur content of the exhaust is not a regulated emission but it produces the noxious sulphur odor frequently smelled in diesel exhaust. In reviewing the variability of the sulphur emission, it was found that the sulphur output is a function of the sulphur content of the fuel. Data were obtained from Reference 2 about two engines which were operated with five different fuels, each having a different sulphur content. The results are plotted in Figure 5.6. A simple linear regression of the data points provided the following equations and their corresponding confidence coefficients:

CAT 3208 Sulphur	$174.01xS + 3.88$; Conf Coef = .974	(E5.1)
DDA 6-71 Sulphur	$146.42xS + 14.50$; Conf Coef = .985	(E5.2)
CAT 3208 SO_4	$397.33xS + 20.77$; Conf Coef = .845	(E5.3)
DDA 6-71 SO_4	$555.94xS + 12.69$; Conf Coef = .974	(E5.4)

RELATIONSHIP OF S AND SO_4 VS. FUEL SULPHUR CONTENT - SAE REPORT 790490, FEB-MAR 79
2 Engines, 5 Fuels



	Regression Line	Confidence Coefficient
CAT 3208 SULPHUR	174.01x+ 3.88	.974
DDA 6-71 SULPHUR	146.42x+14.50	.985
CAT 3208 SO_4	397.33x+20.77	.845
DDA 6-71 SO_4	555.94x-12.69	.974

Figure 5.6 Fuel Sulphur and Particulate Sulphur

The high confidence coefficients show that the sulphur output is a function of sulphur input by fuel. Since $S/SO_4/SO_2$ are not regulated emissions and maximum sulphur content is specified for military procurements of the fuel (0.5% mass CONUS procurement, 0.7% OCONUS Procurement for DF-2, per reference 54), this variable was not included in the analysis for the RE/CBDE for Army MHE. Also data for S/SO4/SO4 not usually available on most engines since it is not regulated.

5.2.2 Engine Performance Utility Variables

Variables considered to provide comparisons of alternative engines for functional performance were fuel consumption, physical engine volume, and brake horsepower (BHP) to engine displacement ratio.

Military diesel fuel #2 (DF2) costs about $1.00 per gallon. This cost is expected to increase faster than general economic inflation within the next decade. The RE/CBDE consumes about ten percent more fuel than the directly injected (open combustion chamber) engine. The relative fuel consumption of the RE/CBDE engine was therefore selected as an appropriate variable for the analysis.

The physical engine volume was considered as a variable for the engine evaluation since it may affect the vehicle's size and consequently its turning radius. The volume of an engine is difficult to quantify in a standard way however, as the data available may include or exclude a wide variety of engine components and the same engine may have widely different volumes depending on the components selected. The result was that the volume of the alternative engines was considered to have too indeterminate an impact on the vehicle profile and turning radius and were not of sufficient import to be included in the analysis.

A variable that was included in the analysis is the brake horsepower to engine displacement ratio. This ratio was included as an indicator of engine durability. The Army places importance on the acquisition of an engine with a long operational life. Many of today's small diesel engines are derived from automotive gasoline engine blocks, which have been modified with diesel cylinder heads and injection apparatus, or

are high-speed engines operating at automotive speeds, well in excess of 3,000 RPM. It is believed that engines which derive their power through torque peaks at above 3,000 RPM or have lightweight blocks and components will not provide the durability desired for the Army MHE application. This is a somewhat judgemental area for analysis, since engine life data are not available or are not directly comparable for diesel engines of the size and type concerned. Although not conclusive, the BHP to displacement ratio provides an indication of engine durability in that higher brake mean effective pressures (BMEP) are expected to result in shorter engine life, unless the bearing areas are greater, higher strength alloys and/or sections are used, and greater cooling is provided. Other potential variables which might be used for comparisons of diesel engines, such as specific HP (HP/lb of engine weight) or specific volume (HP/cu. in. of overall engine) were not considered germane for the MHE application.

5.3 WEIGHTING OF VARIABLES

The weighting of variables for the evaluation of relative merit of the engines was judgementally derived. The analysis is based on the engine emissions of CO, NO_x, and HC and the additional variables of fuel consumption and BHP to displacement ratio. The sum of the variable weights equals 100, or 100 percent. Since the emphasis of the study is upon RE/CBDE engines, the emission variables were emphasized and provide more than half the weight (55 percent). Of the three emissions, CO is the only compound which has been documented as being detrimental to human health in the quantities found in diesel engine exhausts; it was accordingly weighted more heavily than NO_x and HC. Fuel consumption was considered a significant variable and weighted at 25 percent. The remaining variable, BHP to displacement ratio, was weighted at 20 percent. The resultant variable weights are displayed in Table 5.1.

Table 5.1

Evaluation Variables And Their Weights

Variables	Percent
CO	25
NO_x	15
HC	15
Fuel Consumption	25
BHP/Displacement	20
Total	100%

5.4 DUTY CYCLE SELECTION

Manufacturers' engine emission data were provided with a variety of units and for a variety of not directly comparable situations (although data were generally made available in the format of the EPA 13-Mode Test). Dr. Coggins, of Energy Applications, Inc., had modeled an 8-hour shift for his closed-environment emission model under contract to MERADCOM (Reference 56). The model has been operated on the basis of 8-hour shifts. Eight hours is the computational base for this integration analysis, which not only aligns with Dr. Coggins' modeling work, but is also a time period that is appropriate from a normal duty-cycle point of view and is used for the OSHA time-weighted exposure limits (Table 2.3). Although a tactical duty cycle may be a 12-hour shift, the 8-hour, peace-time shift was used for convenience, its commonality, and the uncertainty whether exposure of military soldiers to 12-hour wartime shifts is a greater restraint than peacetime exposure of civilians in eight-hour shifts. Dr. Coggins' work employed an 8-hour shift cycle based on 90 seconds in the shelter and 60 seconds outside the shelter with an average engine load of 23 percent. SAI developed an 8-hour shift duty cycle with a 25 percent average engine load while operating which was approved for use by the sponser (Reference 57, page R-6). The duty cycle used is illustrated in Table 5.2.

Table 5.2 MHE Duty Cycle (8-hour shift)

Load	BHP	Hours	Load x Hours
Off		1.7	0.00
Idle	0	2.0	0.00
25%	12.5	1.0	.25
50%	25.0	3.0	1.50
75%	37.5	.2	.15
100%	50.0	.1	.1
			2.00 / 8 = .25 average load

The 8-hour shift duty cycle at .25 average load is very close to Dr. Coggins' .23 average load used in his model. The emissions in the closed environment of the model (90/150 inside, 60/150 outside) do not relate directly to the total emission computed for this integration analysis. It is anticipated that when Dr. Coggins' model is validated and calibrated, any engine may be simulated in the modeled environment for determining the levels of its emissions in the simulated CSC environment.

To make the engines analyzed directly comparable in power, they were all examined at an output of 50 BHP. This was considered the upper-end range of the power desired for the target MHE - the 4,000 pound forklift truck.

This analysis would apply to engines within the 40-60 BHP range. This range was validated by the analysis given in paragraph 6.1.3. It is considered that the 50 HP analysis would be valid in the 40 to 60 BHP range or the ± 20 percent range. Many of the analyzed candidate engines exceeded 60 BHP, but would not be applicable to the 4000 pound forklift truck. The 6000 pound rough-terrain forklift truck will require a larger engine hence the analysis of a different horsepower range would be desirable.

5.5 DATA REDUCTION

This paragraph describes the process used to convert the raw data received from the engine manufacturers into specific values for emissions and fuel consumption at 12.5, 25, 37.5, and 50 horsepower (BHP) engine output at rated revolutions per minute (RPM).

Data requested of the engine manufacturers is shown by the questionnaire at Appendix E. Requested data included: engine speed, torque, brake horsepower (BHP), brake mean effective pressure (BMEP) (calculated from test data), fuel consumption, brake horsepower specific fuel consumption (BSFC) (calculated from test data), air intake volume, ambient temperature and barometric pressure, exhaust gas volume and temperature, engine noise output, exhaust emissions in parts per million (PPM) of carbon monoxide (CO) nitrogen oxides (NO_x) and hydrocarbons (HC), and exhaust particulates and Bosch Smoke Number. In order to provide a common basis for comparing test data from different engine manufacturers, the engine manufacturers were asked to provide data in accordance with the thirteen mode diesel engine test cycle as described in paragraph 86.336-79 of the Federal Register, Vol. 42, No. 174, September 8, 1977. A copy of these specifications is shown in Appendix E.

The initial review of test data disclosed that it would not be practical to compare the exhaust emission characteristics of different engines by comparing the values in ppm of CO, NO_x, and HC in the engine exhaust, or in envisioned work cycle. The ppm of an exhaust gas component is simply the fraction of the total exhaust gas volume represented by that component. Due to the wide variation in exhaust gas volumes produced by different engines, it was necessary to compare the exhaust emissions of different engines in absolute terms. Grams per hour of each measured exhaust gas component produced by an engine operating at a particular power output were used for this comparison.

Some of the engine manufacturers initially provided emission data in units of grams per hour. Emission data provided in ppm was converted to grams per hour by using the following equations obtained from paragraph 86.1342-86, Calculations, Exhaust Emission, Federal Register, Vol. 46, No. 4, January 7, 1981.

$$HC(gm/hr) = V \times D_{HC} \times HC_{(ppm)} \times 10^{-6} \times 60 \text{ min/hr}$$

$$NO_x(gm/hr) = V \times D_{NO_x} \times K_H \times NO_{x(ppm)} \times 10^{-6} \times 60 \text{ min/hr}$$

$$CO(gm/hr) = V \times D_{CO} \times CO_{(ppm)} \times 10^{-6} \times 60 \text{ min/hr}$$

where:

V = exhaust flow (ft^3/min) at the standard temperature and pressure used for calculation of horsepower

D_{HC} = (average) density of hydrocarbon at standard temperature and pressure (assumed) = 16.33 gm/ft^3 @ 20°C and 760 mm Hg

D_{NO_x} = (average) density of nitrogen oxides at standard temperature and pressure (assumed) = 54.16 gm/ft^3 @ 20°C and 760 mm Hg

D_{CO} = density of carbon monoxide at standard temperature and pressure = 32.97 gm/ft^3 @ 20°C and 760 mm Hg

K_H = Correction Factor = *1.0 for diesel engines*

$HC_{(ppm)}$ = parts per million concentration of hydrocarbons in the exhaust gas sample

$NO_{x(ppm)}$ = parts per million concentration of oxides of nitrogen in the exhaust gas sample

$CO_{(ppm)}$ = parts per million concentration of carbon monoxide in the exhaust gas sample

A sample calculation for CO (gm/hr) using the above expression for the John Deere Engine, Model 3179DF is given below:

EPA Mode	= 10
Engine Speed	= 2500 RPM
Rated Load	= 50%
Brake Horsepower	= 28 @ 29.4°C & 746 mm Hg
Exhaust Gas Volume	= 255 ft^3/min.
Exhaust Gas Temperature	= 430°C
CO	= 275 ppm

Converting exhaust gas volume to 29.4°C and 746 mm Hg

s = standard t = test data

$$V_s = V_t \times \frac{T_s}{T_t} \times \frac{P_s}{P_t}$$

$V_t = 255\ ft^3/min$

$T_s = 29.4^oC + 273.16 = 302.56\ ^oKelvin$

$T_t = 430^oC + 273.16 = 703.16\ ^oKelvin$

$P_s = 746$ mm Hg

$P_t = 746$ mm Hg

$$V_s = 255 \times \frac{302.56}{703.16} \times \frac{746}{746} = 109\ .72\ ft^3/min$$

$$CO_{(gm/hr)} = V_s \times CO \times CO_{(ppm)} \times 10^{-6} \times 60\ min/hr$$

$V_s =$ 109.72 ft^3/min

CO = 31/35 gm/ft^3 @ 29.4°C & 746 mm Hg

CO_{ppm} = 275 ppm

$$CO = \frac{109.72 \times 31.35 \times 275 \times 60}{10^6} = 56.75\ gm/hr$$

Similar calculations were completed for CO, NO_x, and HC, at EPA Modes 8, 9, 10, 11, 12, and 13 representing respectively 100%, 75%, 50%, 25%, and 2% engine load at rated RPM, and 0% load at idle RPM (mode 13). The data derived from these calculations for the John Deere - 3179 DF engine are shown in Table 5.3. Calculated data for all 29 engines used in this analysis are shown in Appendix G.

Table 5.3 Calculated Data, John Deere Engine - Model 3179 DF

EPA Mode	% Rated Load	Engine Speed	HP	Fuel Flow lbs/hr	CO gm/hr	NO_x gm/hr	HC gm/hr
8	100	2500	56	24.49	294	576	31
9	75	2500	42	18.23	52	407	41
10	50	2500	28	13.16	57	305	48
11	25	2500	14	9.48	67	93	49
12	2	2500	1.1	1.45	88	76	51
13	Idle	800	-	1.43	26	23	14

To compare the 29 engines examined in this investigation, it was necessary to establish a standard for engine operations. All engines could then be measured against this standard. Since this study was undertaken to examine the feasibility of obtaining a low emission diesel engine for a 4,000 pound forklift truck, horsepower requirements for this type of vehicle were used for all diesel engines examined. The values selected for this standard are idle (engine running but not under load), 12.5 horsepower, 25.0 horsepower, 37.5 horsepower, and 50.0 horsepower. It was assumed that the horsepower would be generated at the rated/governed RPM for each particular engine.

With the measurement standard selected, it was necessary to determine the fuel consumption of each engine at these performance points, and the associated emission production at each of these points. This was accomplished by linear interpolation between the known value for fuel flow and emission developed at various horsepower settings used in the EPA 13 Mode Emission Test. Graphical representations of these interpolations as used on the John Deere Model 3179 DF engine are shown in Figures 5.7, 5.8, 5.9, and 5.10.

The values for fuel flow and emission at engine idle could be taken directly from corrected test data. The calculated data for the John Deere Model 3179 DF engine are shown in Table 5.4. Calculated data for each of the 29 engines considered in this analysis operating at idle, 12.5 horsepower, 25.0 horsepower, 37.5 horsepower, and 50.0 horsepower are shown at Appendix G.

Table 5.4 Calculated Fuel Flow & Emission Data, John Deere Engine Model 3179 DF

Horsepower	Fuel Flow (lbs/hr)	CO gm/hr	NO_x gm/hr	HC gm/hr
Idle	1.32	26.00	23.00	14.00
12.5	8.54	69.44	91.02	49.23
25.0	12.37	59.14	259.57	48.21
37.5	16.60	53.60	374.21	43.25
50.0	21.80	190.28	503.57	35.28

Finally, calculations were made to determine the total fuel consumed and emissions produced by each engine operating in a forklift truck during a typical 8-hour duty cycle. This cycle is described in paragraph 5.4 and Table 5.2. The following sample calculation demonstrates the method used to obtain the total fuel consumption and emission for each engine.

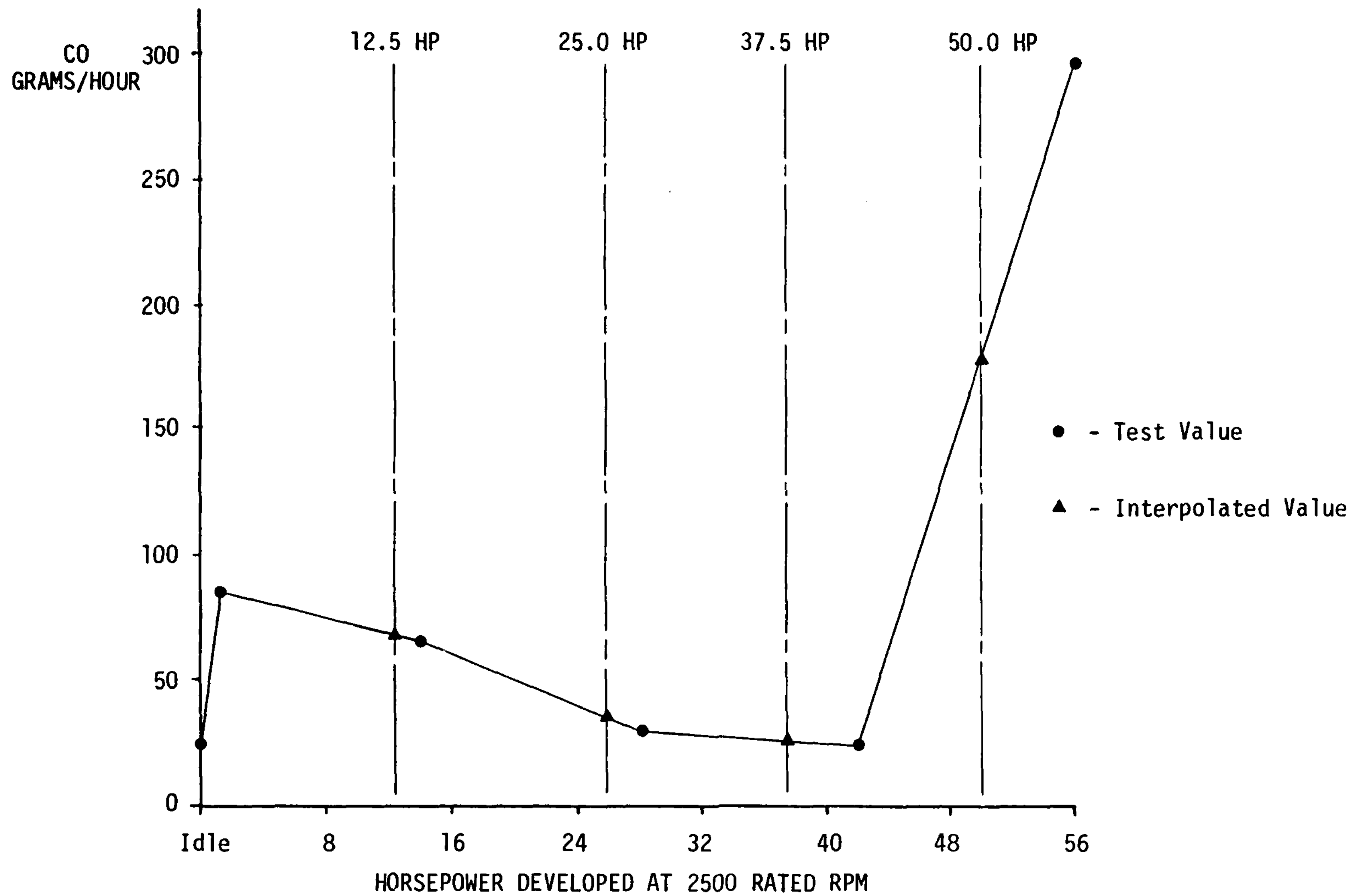


Figure 5.7 JOHN DEERE: 3179 DF -- Carbon Monoxide Emissions

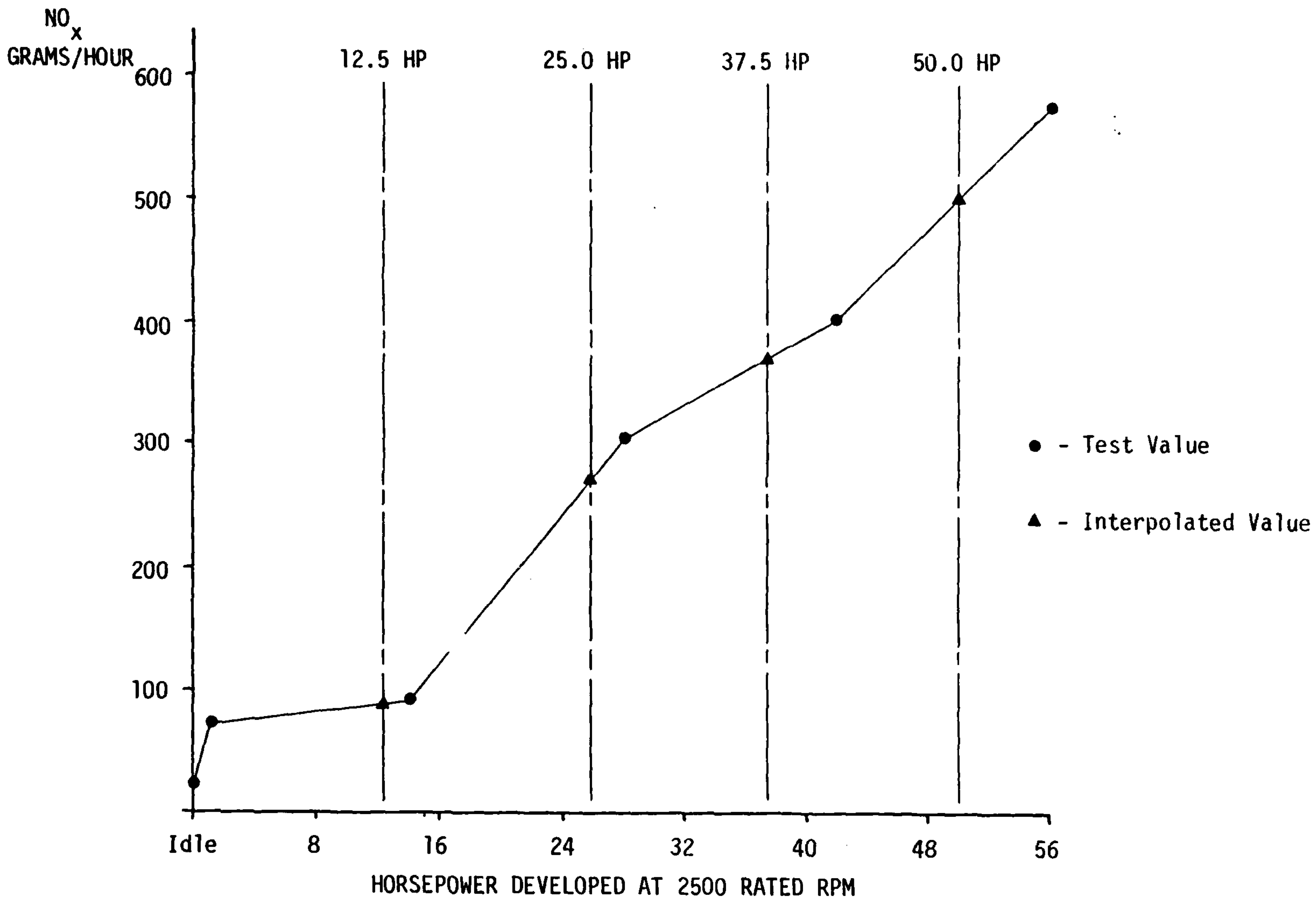


Figure 5.8 JOHN DEERE: 3179 DF -- Oxides of Nitrogen Emissions

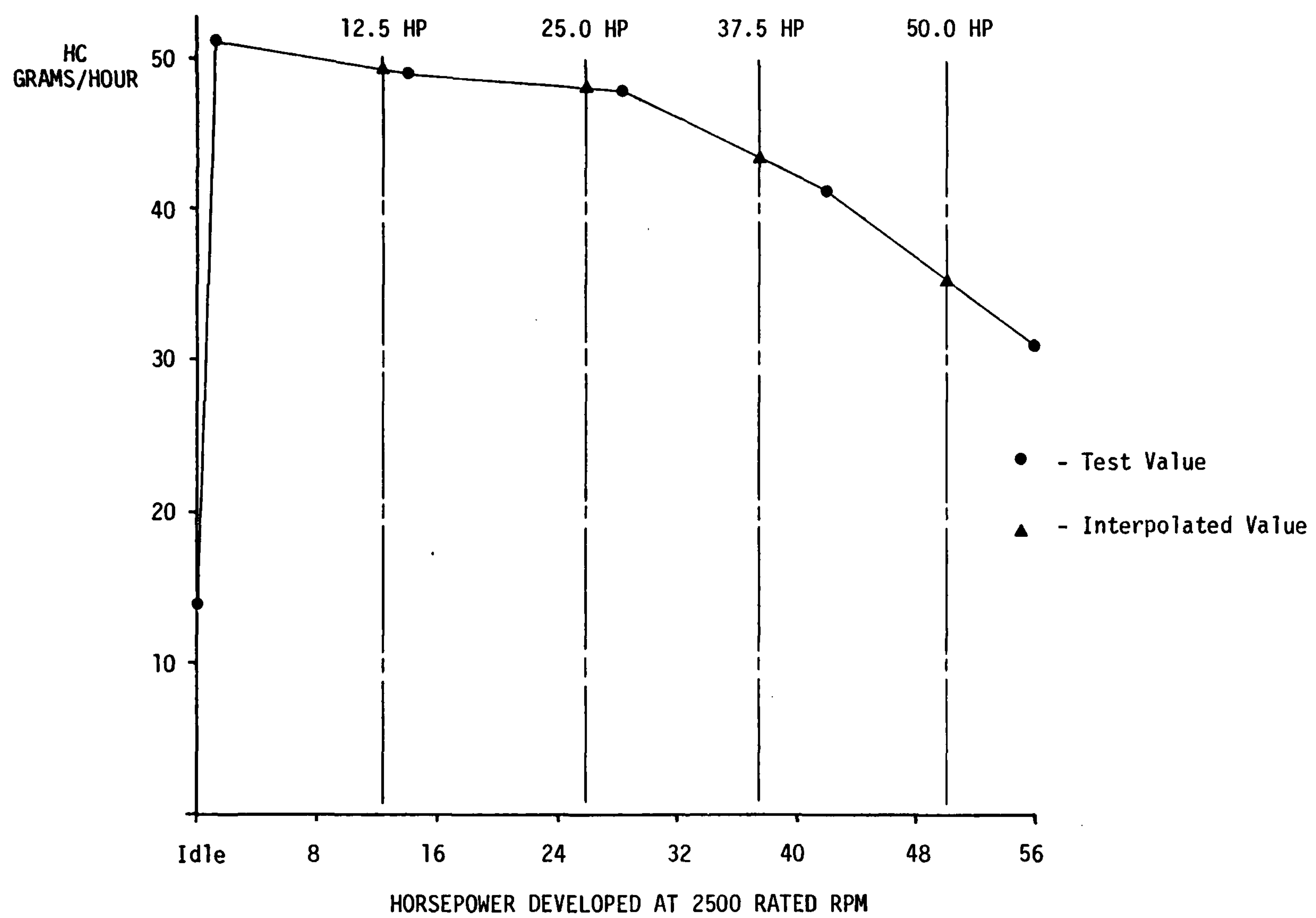


Figure 5.9 JOHN DEERE: 3179 DF -- Hydrocarbon Emissions

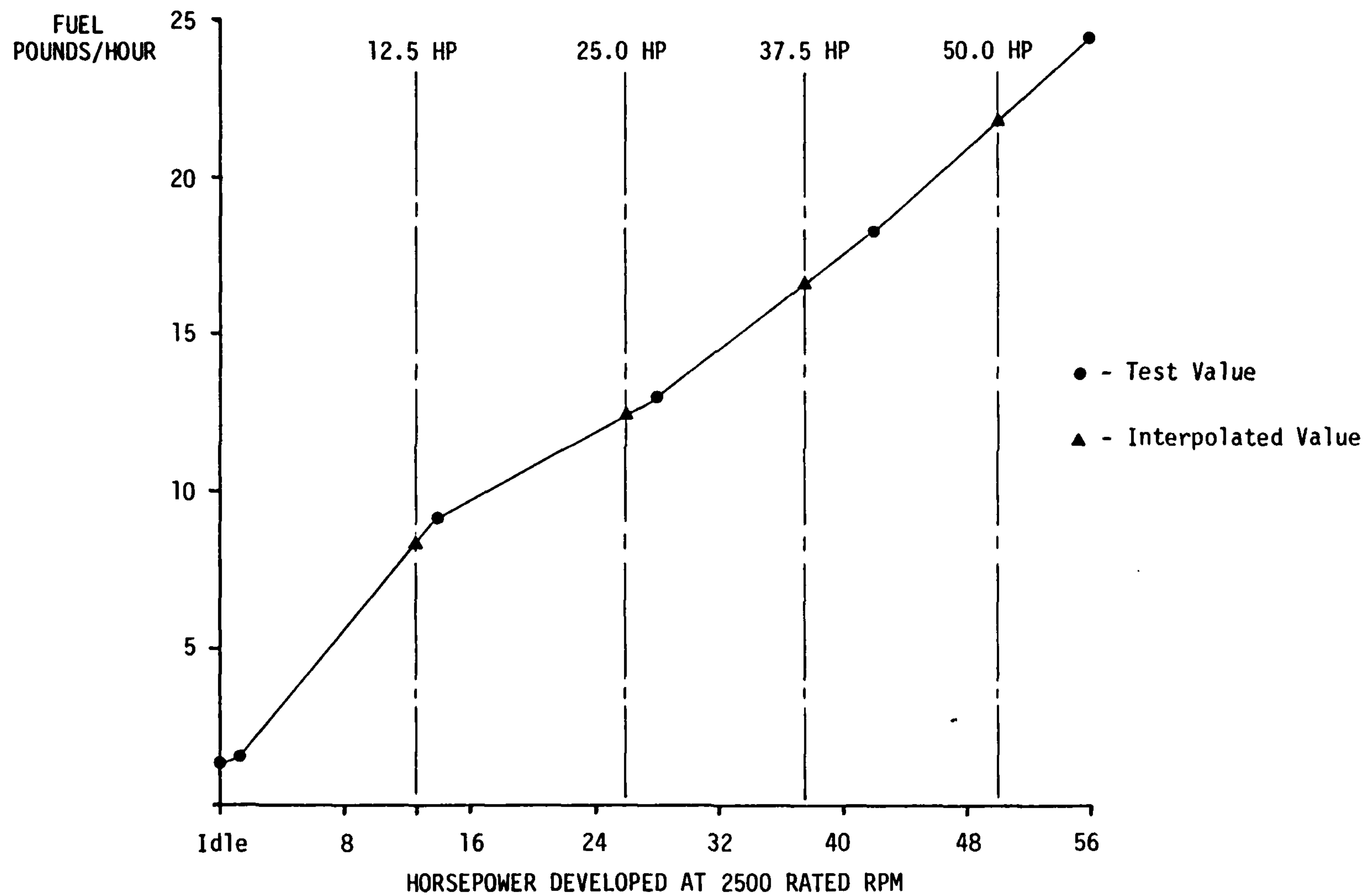


Figure 5.10 JOHN DEERE: 3179 DF -- Fuel Consumption

Sample calculation for total Hydrocarbons produced during an 8 hour shift:

Given: John Deere Engine Model 3179 DF

HC_1 produced at idle = 14.00 gm/hr

HC_{12} produced at 12.5 HP = 49.23 gm/hr

HC_{25} produced at 25.0 HP = 48.21 gm/hr

HC_{37} produced at 37.5 HP = 43.25 gm/hr

HC_{50} produced at 50 HP = 35.28 gm/hr

HC_T = Total HC produced during an 8 hr shift (grams)

$$HC_T = (1.7 \times 0) + (2.0 \times HC1) + (1.0 \times HC_{12}) + (3.0 \times HC_{25}) + (0.2 \times HC_{37}) + (0.1 \times HC_{50})$$

$$HC_T = (2 \times 14.00) + (1 \times 49.23) + (3 \times 48.21) + (0.2 \times 43.25) + (0.1 \times 35.28)$$

$$HC_T = 234 \text{ grams}$$

The results of similar calculations for fuel consumption, carbon monoxide, and oxides of nitrogen are shown in Table 5.5.

Table 5.5 Total Fuel Consumption & Emissions Per Shift, John Deere Model 3170DF

Total fuel used per shift = 54 lbs = 24 kilograms

Total CO produced per shift = 328 grams

Total NO_x produced per shift = 1040 grams

Total HC produced per shift = 234 grams

A small computer program was developed to make the interpolation calculations and the computations for total fuel consumption and total emissions produced per shift. Input and output sheets produced by this program for all 29 engines analyzed in the study are shown in Appendix G.

Three engine manufacturers, AVCO, Ford, and Continental could not provide detailed emission data on all of the engines they submitted for evaluation. They did, however, provide full emission data for one engine in a family of similar engines. These data were used to obtain a first-order estimate of the fuel consumption and emission production of similar engines. Estimated data were used in determining the performance of AVCO engines HR 492HT and HR 392 HT, Ford engine 4610, and the Continental TMD 2.0. Computations for these engines are marked "estimate".

The following procedure was used to estimate the fuel consumption and emission production of these engines:

Step 1. Engines were first examined to insure that following parameters were identical to the test engine:

- Compression ratio
- Cylinder bore and stroke
- Combustion chamber design
- Injectors
- Induction system design (naturally aspirated, turbocharged, or turbocharged and aftercooled)
- Rated RPM, BMEP, and specific fuel consumption (lbs/HP hr)

Step 2. As the above parameters were nearly identical for the members of each of the engine families, it was assumed that the horsepower developed at rated RPM, the fuel consumption, and the emissions produced by similar engines would be directly proportional to engine size (displacement). For example, the 4-cylinder AVCO HR 492 HT engine would produce 2/3 the horsepower and emissions of the 6-cylinder AVCO HR 692 HT engine. This assumption is supported by AVCO's rating of the HR 492 HT at 86 horsepower, which is 2/3 the 129 horsepower rating of the HR 692 HT.

Step 3. Values were calculated for fuel consumption, CO, NO_x, and HC at rated RPM by multiplying the values by the ratio of engine displacements to obtain the estimated value for an engine without test data.

A partial comparison of the AVCO engines is shown in Table 5.6. Test data were available for the 6 cylinder HR692HT engine. Physical data were available for the 4-cylinder HR492HT and the 3-cylinder HR392HT. The estimated emission values for the HR492HT engine are 2/3 of the HR692HT values and the estimated values for the HR392HT engine are 1/2 the HR692HT values.

Table 5.6. AVCO Engine Comparison

PARAMETER	ENGINES		
	HR692HT	HR492HT	HR392HT
Number of Cylinders	6	4	3
Compression Ratio	22:1	22:1	22:1
Displacement (cm)	3589	2393	1794
Bore and Stroke (mm)	92x90	92x90	92x90
Combustion Chamber	Pre-Combustion	Pre-Combustion	Pre-Combustion
Injectors	Bosch	Bosch	Bosch
Aspiration	Turbocharged	Turbocharged	Turbocharged
Rated RPM (DIN6270B)	3800	3800	3800
BMEP (Kg/cm^2)	8.51	8.51*	8.51*
Fuel Consumption (gr/HPhr)	202.5	202.5*	202.5*
Horsepower	129	86*	64*
Fuel Consumption @ Rated HP (lbs/hr)	59.22	39.48*	29.61*
CO @ Rated HP (gm/hr)	107	71*	53*
NO_x @ Rated HP (gm/hr)	390	260*	195*
HC @ Rated Hp (gm/hr)	16	11*	8*

* Estimated values

SECTION VI
ORDER OF MERIT

6.1 ANALYTIC TECHNIQUES

The analysis of engine data provides input toward selection of a RE/CBDE for test in forklift trucks and possible procurement for the Army MHE inventory for both general use and use within CSC environments. In considering various analytic techniques for determining an order of merit, a number of conditions were reviewed, including the following:

- The statistical sample of manufacturer response
- Utility analysis
- Validity of the 40-60 BHP analysis range

Each of the above considerations is discussed below.

6.1.1 Statistical Sample of Manufacturer Responses

A data collection questionnaire was developed, along with an instruction sheet, as the vehicle to query manufacturers for engine data. The draft questionnaire was forwarded to three manufacturers in early November 1982 for review and telephonic feedback regarding the objectivity of the questionnaire vis-a-vis RE/CBDEs. Some minor changes were made to the questionnaire as a result of the informal feedback. The initial mailing of questionnaires was completed on 8 November 1982. Included in the initial mailing was a cover letter indicating that the responses were due back to SAI by 15 December 1982. Appendix E includes a copy of the questionnaire package.

A total of 85 questionnaires were mailed. Of these, 62 were mailed to 49 different manufacturers, resulting in 22 replies of which 17 provided engine data. The total response rate from manufacturers of 45 percent is considered good but not excellent. Responses were received from all manufacturers of known low-emission diesel engines. It is considered unlikely that there is a commercially available, free-

world RE/CBDE for which data were not obtained and which is significantly superior to those examined in this analysis. There is, however, insufficient data upon which to build a comprehensive technology data base for diesel engines in the 35-80 BHP range, including open-combustion chamber engines.

Not all of the data submitted were complete with respect to emissions. Engine data were received on 80 engines, but only 29 could be analyzed for emissions. The 29 analyzed engines do include the known low-emission diesel engines. Each manufacturer not supplying emission data was telephoned to determine the availability of emission data, resulting in the receipt of some additional data.

Fourteen letters were mailed to manufacturers or assemblers of forklift trucks. Many in this category phoned to ensure that data were received about the engines they normally install in their trucks (the data were provided in all cases), but no questionnaires were completed by forklift manufacturers or assemblers.

The remaining nine questionaires were mailed, as a courtesy, to other contractors, associations, and individuals interested in the RE/CBDE analysis. A tabulation of the mailings and responses is given in Table 6.1. The mailing list and responses received are in Appendix F. Selected data extracted from the responses are at Appendix G.

6.1.2 Utility Analysis

The variables of interest were defined, utility curves developed, and weighting factors established for the analysis as described in Section V of this report. The data supplied were corrected to a common denominator, also as described in Section V. A computer program was developed which takes the engine data as input, applies the utility function and weighting factors, and provides a rank-ordered listing of the candidate engines by total utility. The computer program (in FORTRAN on a VAX 11/780) has a computational flow as shown in Figure 6.1. Table 6.2 is a copy of the output of the rank-ordered candidate engines. Total utility is shown to two places; however, most of the differences between adjacent engines on the list are essentially

Table 6.1 Responses from Industry

	Questionnaires Mailed	Responses		Engine Candidates		
		Expected	Received	Expected	Received	Analysed
Engine Manufacturers	49	40	22	200	80	29
Duplicates	13					
Forklift Manufacturers	14	0	0			
Others	9	0	0			
Total	85	40	22			

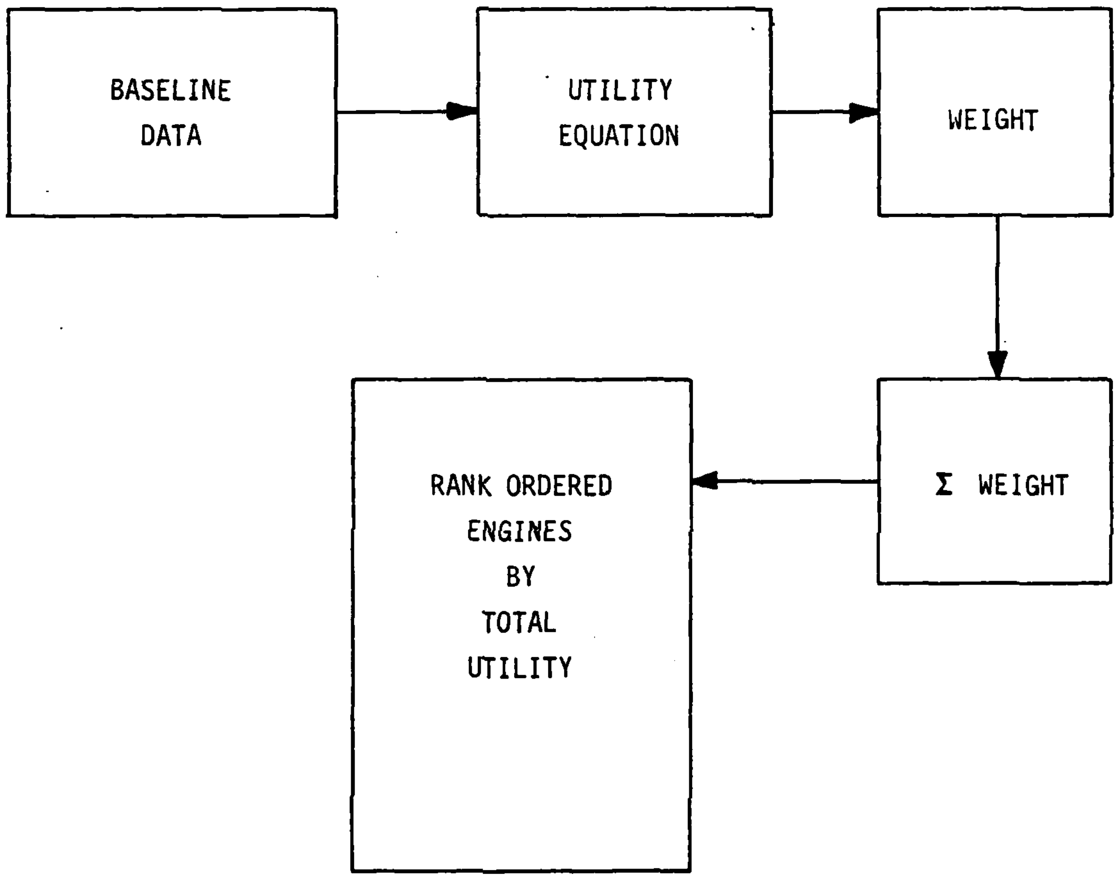


Figure 6.1 Computer Program Flow Diagram

Table 6.2 Engine Candidates Ranked by Total Utility

**DIESEL ENGINE UTILITY--SCIENCE APPLICATIONS INC **

ENG NUM	--FUEL-- CONSP	FUEL-UTL RAW	FUEL-UTL WTD .25	--CARBON MONOXIDE-- CO	CO-UTL RAW	CO-UTL WTD .25	---NITROGEN OXIDE-- NOX	NOX-UTL RAW	NOX-UTL WTD .15	---HYDRO CARBONS--- HC	HC-UTL RAW	HC-UTL WTD .15	---HORSPWR/DISPL--- RATIO	RATIO-UTL RAW	RATIO-UTL WTD .20	*****TOTAL***** UTILITY
29	22.0	0.71	0.18	147.	1.03	0.26	360.	1.11	0.17	21.	1.13	0.17	.023	0.52	0.10	0.88
14	24.0	0.56	0.14	94.	1.15	0.29	796.	0.73	0.11	25.	1.12	0.17	.016	0.85	0.17	0.87
13	22.0	0.71	0.18	225.	0.86	0.22	529.	0.96	0.14	137.	0.77	0.12	.016	0.85	0.17	0.82
28	23.0	0.63	0.16	289.	0.72	0.18	502.	0.99	0.15	34.	1.09	0.16	.018	0.78	0.16	0.81
4	25.0	0.48	0.12	218.	0.88	0.22	368.	1.10	0.17	40.	1.08	0.16	.023	0.54	0.11	0.77
11	27.0	0.33	0.08	146.	1.03	0.26	924.	0.61	0.09	33.	1.10	0.16	.016	0.85	0.17	0.77
19	21.[illegible]	0.78	0.20	248.	0.81	0.20	749.	0.77	0.12	151.	0.73	0.11	.020	0.66	0.13	0.76
17	25.0	0.48	0.12	146.	1.03	0.26	985.	0.56	0.08	145.	0.75	0.11	.022	0.60	0.12	0.70
23	20.0	0.86	0.21	278.	0.75	0.19	1528.	0.08	0.01	77.	0.96	0.14	.022	0.57	0.11	0.67
22	21.0	0.78	0.20	320.	0.66	0.16	1070.	0.48	0.07	102.	0.88	0.13	.023	0.52	0.10	0.67
18	24.0	0.56	0.14	319.	0.66	0.16	788.	0.73	0.11	203.	0.57	0.08	.020	0.66	0.13	0.63
8	24.0	0.56	0.14	328.	0.64	0.16	1040.	0.51	0.08	234.	0.47	0.07	.019	0.72	0.14	0.59
27	27.0	0.33	0.08	426.	0.43	0.11	674.	0.83	0.12	137.	0.77	0.12	.019	0.75	0.15	0.58
12	22.0	0.71	0.18	343.	0.61	0.15	1564.	0.05	0.01	209.	0.55	0.08	.020	0.70	0.14	0.56
26	27.0	0.33	0.08	431.	0.42	0.10	569.	0.93	0.14	235.	0.47	0.07	.020	0.70	0.14	0.54
3	30.0	0.11	0.03	143.	1.04	0.26	830.	0.70	0.10	35.	1.09	0.16	.036	-0.11	-0.02	0.53
20	25.0	0.48	0.12	393.	0.50	0.12	1326.	0.26	0.04	111.	0.85	0.13	.022	0.57	0.11	0.53
9	23.0	0.63	0.16	370.	0.55	0.14	1486.	0.12	0.02	303.	0.25	0.04	.019	0.71	0.14	0.49
25	25.0	0.48	0.12	627.	-0.01	0.00	741.	0.77	0.12	254.	0.41	0.06	.018	0.77	0.15	0.45
24	26.0	0.41	0.10	727.	-0.22	-0.06	487.	1.00	0.15	195.	0.59	0.09	.018	0.75	0.15	0.44
15	24.0	0.56	0.14	531.	0.20	0.05	844.	0.68	0.10	393.	-0.03	0.00	.021	0.61	0.12	0.41
10	25.0	0.48	0.12	430.	0.42	0.10	1638.	-0.02	0.00	298.	0.27	0.04	.020	0.70	0.14	0.40
16	26.0	0.41	0.10	540.	0.18	0.05	944.	0.60	0.09	296.	0.28	0.04	.022	0.57	0.11	0.39
2	35.0	-0.27	-0.07	173.	0.98	0.24	1052.	0.50	0.07	48.	1.05	0.16	036	-0.10	-0.02	0.39
21	23.0	0.63	0.16	897.	-0.59	-0.15	868.	0.66	0.10	153.	0.72	0.11	019	0.74	0.15	0.37
6	25.0	0.48	0.12	742.	-0.26	-0.06	657.	0.85	0.13	[illegible]27.	0.18	0.03	019	0.72	0.14	0.35
7	27.0	0.33	0.08	676.	-0.11	-0.03	650.	0.85	0.13	491.	-0.33	-0.05	.019	0.70	0.14	0.27
5	25.0	0.48	0.12	747.	-0.27	-0.07	998.	0.55	0.08	467.	-0.26	-0.04	018	0.79	0.16	0.26
1	47.0	-1.17	-0.29	238.	0.83	0.21	1438.	0.16	0.02	66.	0.99	0.15	036	-0.12	-0.02	0.07

negligible. Ranking of engines with the same value of total utility shown was based on generation by the program of three "significant" digits. Relative engine rankings for each utility variable are shown in Table 6.3. The largest variations in ranking from that of total utility occur in the ranking according to BHP to displacement ratio and fuel consumption. The rankings of the highest, median, and lowest-rated engines are tracked through the table to show variations among the different parameters, and sensitivity to the weighting and range of utility value assigned. Changes in either the weight assigned each variable or in the spread of utility value between the best and poorest of the engines being ranked could result in local reordering of the overall engine rankings. The highest ranking engine in the analysis (the Continental 2.0 Litrengine) has a high ranking in all of the variables with the exception of a low rating in BHP to displacement. The second-ranked engine (the Deutz F3L-912W) ranks high in all categories with the exception of moderate ratings for fuel consumption and NO_x emissions. Changes in the relative importance assigned to BHP to displacement ratio and fuel consumption, or the addition of additional considerations could easily reverse the relative ranking of these engines.

Histograms were prepared for the BHP and the total utility of the 29 analyzed engines. These histograms are depicted in Figure 6.2. The top two utility engines stand by themselves, followed by a grouping of five engines, followed by another gap. The utility theory methodology resulted in a good differentiation of engine candidates, although the first position was a near tie. The grouping of engines has no statistical significance but is normal with the use of utility theory.

6.1.3 Validity of the 40-60 BHP Analysis Range

Data were requested for engines in the 35-80 BHP range; but an 80 BHP engine may not be compared fairly to a 40 BHP engine. The engine desired is for a 4,000 pound forklift truck. This normally requires an engine in the 40-50 BHP range; 50 BHP was selected as the analytic basis for computations. To examine the validity of the 40-60 BHP range analytic results, reversed parallel scales of BHP and total utility (increasing BHP and decreasing utility) were prepared and the positions of the different engines on the scales were identified (Figure 6.3). Examination of Figure 6.3

Table 6.3 Comparison of Engine Rankings for Individual Utility Variables

(The assigned engine numbers are listed in order of decreasing utility value. Bracketed engines have same value. Engines identified at Table 6.4)

Total Utility	Fuel Consp.	BHP/ Displ.	CO	NO_x	HC	Wtd $CO+NO_x$ + HC
29	23	14	14	29	29	29
14	19	13	3	4	14	14
13	22	11	29	24	11	4
28	29	5	11	28	28	3
4	13	28	17	13	3	11
11	12	25	2	26	4	28
19	28	27	4	6	2	13
17	9	24	13	7	1	2
23	21	21	1	27	23	17
22	14	8	19	19	22	19
18	18	6	23	25	20	1
8	8	9	28	14	13	22
27	15	12	22	18	27	18
12	4	26	18	3	17	27
26	17	10	8	15	19	23
3	20	7	12	21	21	8
20	25	19	9	11	24	26
9	10	18	20	16	18	20
25	6	15	27	17	12	12
24	5	17	26	5	8	9
15	24	23	10	22	26	24
10	16	20	15	8	25	25
16	11	16	16	2	16	16
2	27	4	25	20	10	15
21	26	29	7	1	9	10
6	7	22	24	9	6	6
7	3	2	6	23	15	21
5	2	3	5	12	5	7
1	1	1	21	10	7	5

Note: The ranking of the highest, medium, and lowest-rated engines are tracked through the table to show variations among the different parameters and sensitivity of the weighting and range of utility values assigned.

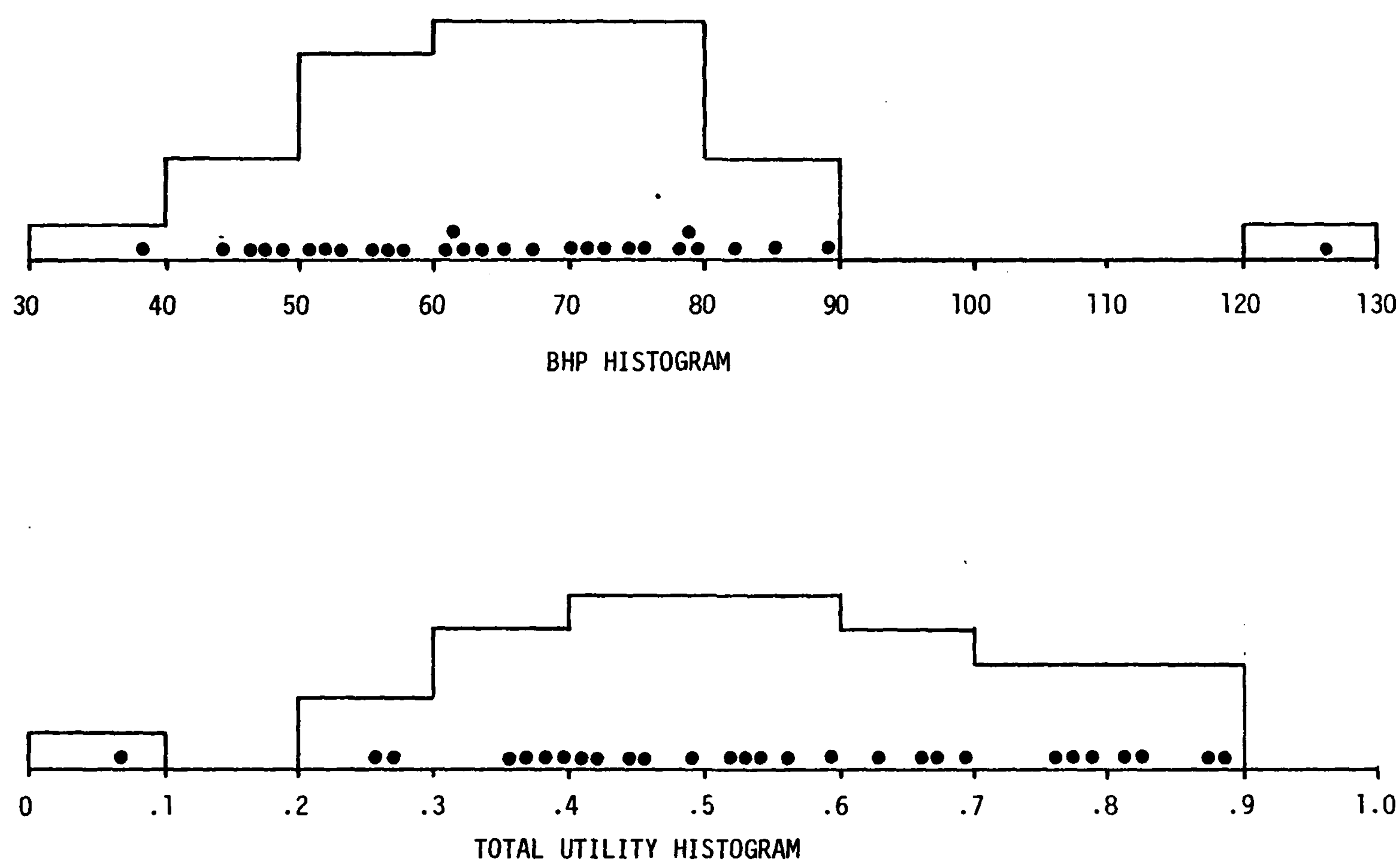


Figure 6.2 Histograms of BHP and Total Utility

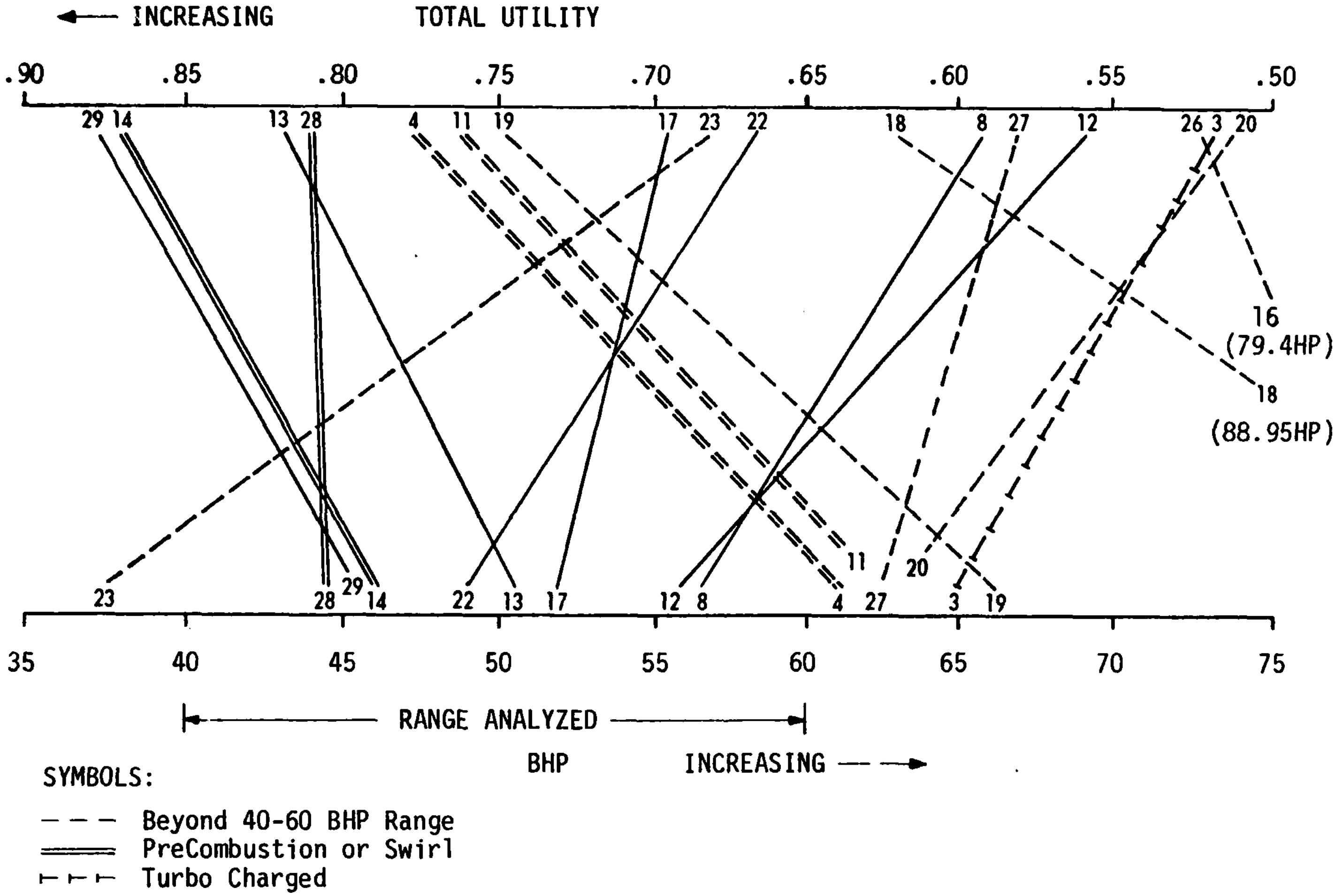


Figure 6.3
Total Utility - BHP Nomograph
(Engines with Utility > .5, 16 Engines)

substantiates the appropriateness of the 40-60 BHP range for engine size and shows the impact of precombustion (and high-swirl) chambers upon low emissions. The immediate conclusion is that the smallest engine should not have more than the minimum required BHP. The precombustion chamber engines have the highest total utility. Further, upon entry into the 60-80 BHP range of engines, precombustion engines (11 and 4) show a high comparative utility followed closely by a direct-injection (open combustion chamber) engine (19). The selection of a RE/CBDE in the 60-80 BHP range would require an additional analysis, since the variable data would be extracted at different points from nonlinear emission and fuel consumption curves. For the 50 BHP baseline analysis, the comparative scales show a clear delineation of engine differences at both 40 and 60 BHP.

The results of the utility analysis do not support a conclusion relative to the desirability of turbocharging in a RE/CBDE as data were only available on a limited number of engines, the turbocharged engines were open combustion chamber design, and the turbocharged engines had horsepowers above the 40-60 BHP range. The apparent relationship between engine horsepower and utility, shown on Figure 6.3, does not provide a clear distinction between turbocharged and naturally-aspirated open combustion chamber engines apart from the assessment that excess power capacity for any basic engine design probably is accompanied by lower utility value (in the utility weighting and valuing system used in this study).

6.2 SUMMARY ORDER OF MERIT

The top-ranked engines based upon utility (Table 6.4) are listed below:

Priority	No.	Engine Make/Model	BHP	Total Utility
1	29	Continental TMD 2.0	46.1	.88
2	14	Deutz F3L-912W	46.6	.87
3	13	Deutz F3L-913G	50.3	.82
4	28	Perkins 4.154	44.9	.81

Table 6-4 Summary of Analyzed Engines

Eng No.	Manufacturer/Model	BHP	Disp (cc)	(cu. in.)	Features	Total Utility Ranking
1	AVCO HR 692 HT	128.6	3589	219	Turbo	29
2	HR 492 HT (Est)	85.0	2393	146	Turbo	23
3	HR 392 HT (Est)	64.3	1800	110	Turbo	16
4	Continental TMD 2.7 Litreng	61.4	2700	165	High Swirl	5
5	John Deere 4276 DF	80.0	4520	276		28
6	4239 DF	75.0	3920	239		26
7	4219 DF	70.0	3600	220		27
8	3179 DF	56.0	2940	179		12
9	3164 DF	52.0	2690	164		18
10	Duetz F4L 912	73.7	3770	230		22
11	F4L 912W	62.2	3770	230	Pre comb	5
12	F3L 912	55.3	2827	173		14
13	F3L 913G	50.3	3064	187	High Swirl	3
14	F3L 912W	46.6	2827	173	Pre Comb	2
15	Isuzu 4BD1	82.0	3856	235		21
16	4BC2	72.0	3268	199		23
17	C240	51.0	2369	145		8
18	Ford 6601	89.0	4392	268		11
19	4610 (Est)	66.7	3294	201		7
20	Hatz 4L30 S.Z	62.6	2832	173		16
21	D106	56.5	3021	184		25
22	3L30 S/Z	48.9	2124	130		9
23	2L40 S/Z	37.8	1716	105		9
24	Kubota V4300-B	79.0	4292	262		20
25	V400-B	72.0	3983	243		19
26	Perkins 4.2482	79.4	4070	248		15
27	4.2032	61.6	3328	203		13
28	4.154	44.9	2500	153	High Swirl	4
29	Continental TMD 2.0 Litrengine	46.1	2000	122	High Swirl	1

Each of the above engines appears to be capable of installation in forklift trucks. The two Deutz engines and the Perkins engines are currently being installed in commercial forklift trucks. The more recently (1983) introduced Continental engine is currently being installed on Miller "Big 25D" welders.

SECTION VII
DIESEL POWERED MHE IN THE CSC ENVIRONMENT

7.1 GENERAL SUITABILITY

As a matter of mission need, the Army must be able to move missiles and ammunition to and from storage facilities with reliable trucks on a round-the-clock basis. A need for electrically-operated trucks will continue to exist for those facilities where ammunition components are produced and assembled. For general ammunition handling, the electric trucks are not well suited for continued operation since battery packs provide power for only a few hours of operation.

Although electric trucks may be part of the organizational equipment, much of the Army's material handling in closed, unventilated warehouses in overseas areas (e.g., FRG) is done by gasoline engine trucks. The climate is such that doors may be opened to ventilate the area only when the levels of the perceptible emission products become more unpleasent than the resulting chill. Personnel are exposed in such areas for their entire work weeks in both warehousing and supply administration tasks. Diesel engine powered trucks are more capable than electric-powered trucks in accomplishing the material-handling tasks. Diesel engines also have maintainability, reliability, and fuel advantages over gasoline engines where weight or RPM are not factors. Both the diesel and gasoline engine trucks produce exhaust emissions which are of concern in the CSC environments.

The primary focus of this effort is on the relative and absolute suitability of low-emission diesel engines in Army MHE for the support of continuous operations, peacetime or wartime. The Army's primary orientation must be on readiness for wartime operations, when round-the-clock operations and 12 hour shifts, 7-day work weeks for ammunition and material-handling operations are anticipated. It must also be recognized, however, that RE/CBDE-powered MHE procured for CSC environment operations will expose peacetime warehouses to emission concentrations over extended periods.

7.1.1 Fuel Suitability

The current Army fleet of engine-driven forklift trucks for the load capacity and applications considered in this effort is gasoline powered. Gasoline is dangerous to store and use compared to diesel fuel, and the emissions of the gasoline engines are not suited for CSC applications. Propane and methanol (and other alcohols) are excellent low-emission fuels, but propane is extremely dangerous to store and use, and neither are available in the military fuel logistic system. Most military equipment operates on DF or JP grade fuels and hence these are generally available to support forklift operations. All of the analyzed RE/CBDEs will operate on either fuel without significant readjustment to engine parts. Of the presently logistically available fuels, diesel is the ideal fuel for military forklift operations.

7.1.2 Maintenance Suitability

Two aspects of maintenance suitability must be considered as applied to forklift truck power units. The first aspect is the *standardization of trucks and engines* and the second is the training of maintenance personnel.

The benefits of standardization are especially applicable to special purpose, high peacetime and wartime operational use, engine driven equipment for which there are a multitude of potential manufacturers in a highly competitive market. These factors all fit engine-driven forklift trucks. Successive competitive procurements, using the same performance specifications, often result in the introduction of new models with each new procurement, with all of the attendent provisioning, documentation, and testing. Army experience shows that competitive, major procurements to performance specifications invariably result in the lowest per unit direct procurement cost. The cost in life-cycle expenses and the impact on readiness and operational availability (especially in a war theater) are much higher with this type of procurement. Equipment of this type typically may have between 3000 and 4000 provisioned line items, of which 800 to 1000 must be added to the supply system. Use of an engine new to the military supply system may increase the number of new line items, especially when that engine is not a member of a manufacturer's family of engines where other

members of the family have already been provisioned. Actions such as restricted deployment of models by theaters have been used to reduce the logistic burden; however, the experience of the Korean and Vietnamese conflicts are that in a build-up of forces, every model in the inventory may be deployed to the same theater, resulting in a situation (as was acutely experienced in Vietnam) in which parts necessary to maintain and repair non-standardized, heavy-use, engine-driven equipment, such as forklift trucks and generator sets, cannot be kept in stock or made available quickly enough to avoid extremely high deadline rates and ineffective cannibalization.

The Army has 20 different makes and models of forklift trucks in the 4000 pound capacity range. A multi-year procurement for replacement of the current gasoline engine powered truck with a standard RE/CBDE truck would provide life cycle cost benefits which are large but difficult to credibly quantify. Further, having a large number of identical operating units would provide a better steady-state and surge parts supply base than is provided by having numerous, relatively low quantity models. The advantage of having one type injector on the repair parts shelf instead of a dozen or so carburetors, for example, must be advantageous (the economics of standardization are not a part of this analysis). Further benefits would accrue if the model were selected as a formal military standard item and if a DoD standardization program for forklift trucks were established (as for mobile electric power, reference 58). Problems associated with long-range standardization relate to the reduction of competition (higher procurement costs and concern over procurement policy), the avoidance of possibly available new technology in subsequent procurement, and the historical record of constant minor changes in engine design or components made by manufacturers such that eventually the engines for the military procurement must be made as a separate lot or on a different line (and at a higher, non-competitive price to the equipment manufacturer).

The training benefits for lift operators and mechanics having a single diesel engine forklift truck model are apparent. An additional advantage of diesel power is that most army vehicles are now diesel powered; diesel mechanics are therefore generally available to perform maintenance on the engines.

7.1.3 Suitability in the Closed/Semi-Closed Environment

This effort did not establish the fact that use of RE/CBDE-powered forklift trucks in CSC environments do not present a health hazard. The evidence shows that there are substances emitted by RE/CBDE which, in sufficient concentration, are toxic and/or irritating and/or carcinogenic, and that concentration levels for individual substances will probably be below statutory maximums in most applications. However, the RE/ CBDE emissions are a complex mixture of toxic and irritating substances whose synergistic or additive effects have not been investigated and whose interactions and secondary or break-down products in the CSC environment are uncertain. Further, there may be a serious enhancement of the action of a major emission component (CO) caused by the presence of carbon dioxide and water vapor (generally considered as benign).

The results of the analysis are the conclusions that there are insufficient data to state that use of RE/CBDE-powered forklift trucks would be safe in some of the CSC environments and personnel exposures to be expected, but that it is possible to comparatively rank candidate engines for the application based on individual major emission component levels. For example, one engine (engine number 29 in Table 6.4) would emit less than one-fourth the grams of NO_x per simulated work cycle than one of the other engines (number 10). Carbon monoxide emissions would range from a low of 94 grams (number 14) to a high of 897 grams (number 21) per simulated shift. These variances exemplify some of the differences between RE/CBDE and open combustion chamber diesel engines.

Exposure to high or prolonged concentrations of diesel engine exhaust is generally considered to be "bad" for humans. This analysis found no conclusive documentation regarding specific long-term "bad" effects to humans from exposure to diesel exhaust, per se. Planned field testing of RE/CBDE engines in controlled CSC environments should provide measurements of currently regulated emissions. The testing is not expected to resolve the human hazard issues.

The initial outputs from Dr. Coggins' emission model (Reference 56) show that regulated emissions do not exceed OSHA and other standards. The particles in diesel exhaust might impact human health in the long term by causing conditions similar to "black," "grey," "brown," and "white" lung (although diesel particulates are very small, averaging .5 microns) with the additional complication of the known presence of known carcinogens. The impact of frequent exposure to gaseous emissions is also not sufficiently quantified.

Other elements of the suitability of RE/CBDE-powered MHE for CSC environment operation are the odor and obscuration from the exhaust. These are principally subjective, as sensitivity to breathing and to the eyes vary with each individual. Diesel engine exhaust has a generally unpleasant odor. RE/CBDE exhaust emissions have been observed to be less than open combustion chamber direct injection engines, however; if it is proved that there is no hazard associated with the emissions, the odor levels may be tolerable. If there is a degree of hazard it is probable that the odor and visible smoke will be assumed to relate to that hazard (there may be no linkage in reality) and be highly objectionable. Further, it is probable that the odor and smoke levels produced in CSC environments will be above the threshold at which they are irritating to some and below the level at which they are irritating to all of the prospective peacetime and wartime personnel involved.

7.2 RESTRICTIONS ON USAGE

The operation of RE/CBDEs in CSC environments may cause an unsuitable level of discomfort to some individuals - whether it is actual or psychosomatic makes no difference. Corrective action would be in order for these situations. The following discussion on usage restrictions is not exhaustive but is intended to provide some considerations on potential restrictions.

Most ammunition storage facilities and much of the temperate and colder climate supply warehouses do not possess positive ventilation but depend upon open doors and limited roof vents (if installed at all) for ventilation. When the air is nearly still and air turnover approaches zero, operating time in the igloo or storage area may

be decreased, or staggered over a longer period of time. In emergencies or prolonged low air turnover situations, individuals could wear a man-portable compressed air supply. Military individual masks and collective protection systems designed for NBC environments are highly effective for protection against particulates and gaseous hydrocarbons. They do not protect against carbon monoxide and may not protect against NO_x or CO_2 (Reference 5).

7.3 POTENTIAL SOLUTIONS FOR RESTRICTIONS

Built-in provisions to protect the operator (but not others in the area) against high concentration levels could include a vehicle-mounted compressed air supply or additional exhaust treatment. The compressed air supply would protect against all breathed hazards and depending on mask design could also provide eye protection. Exhaust treatment could eliminate particulates and absorb/adsorb much of the hydrocarbon and sulphur compounds. Filters effective for NBC protection do not generally remove all of the exhaust components of concern.

Another potential solution would be the provision of a flexible exhaust system vented to the outside. This flexible exhaust pipe could be supported from a counter-balanced swinging boom or trolley, but this could severely constrain the equipments' operation; igloos may also be ventilated.

The potential solutions of placing the operator in a regulated environment or removing the diesel exhaust from the CSC environment must be weighed against the cost of implementing the solutions and the other forklift alternative of battery power.

7.4 UNCERTAINTIES

The key uncertainty about integrating RE/CBDEs into the Army inventory rests with the short- and long-term impact of undesirable emissions upon humans in CSC environments, which includes the uncertain synergism of the various emission compounds. These uncertainties are not only for forklift operators but also for other personnel working in the same CSC environments. It may also vary with age group,

sex, and physical condition. Some emissions cause irritation to mucous membranes for which different people have different levels of tolerance. Tolerances to odors are similarly variable. Odor levels are no longer measured with human panels but are measured with instruments which are calibrated to the results of the human test panel outputs.

The uncertainties reside with chemical effects of diesel emissions in human beings. A task of the analysis was to review pertinent material to document the occupational health and hygenic hazards which result from exposure to diesel exhaust. The study found and recommended maximum regulated levels for many diesel exhaust components. References were located which suggest that those maximum levels may be too high, and also that maximum levels may be appropriate for additional diesel exhaust components.

AD-A128 408 REVIEW AND ASSESSMENT OF REDUCED EMISSIONS/CLEAN BURNING DIESEL ENGINES F..(U) SCIENCE APPLICATIONS INC MCLEAN VA J M DAUGHERTY ET AL. 12 MAY 83 SAI-84-170-WA 2/3

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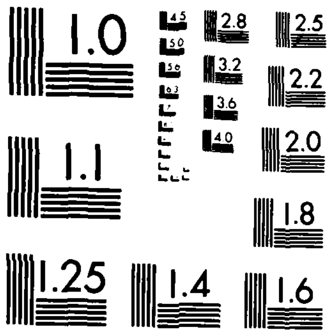

MICROCOPY RESOLUTION TEST CHART
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APPENDIX A

GLOSSARY

ACC	Acceptable Ceiling Concentration
ACGIH	American Conference of Government Industrial Hygenists
AEHA	U.S. Army Environmental Hygiene Agency
ASTM	American Society for Testing and Materials
BHP	Brake Horse Power
BMEP	Brake Mean Effective Pressure
BOI	Basis of Issue
BOIP	Basis of Issue Plan
BSFC	Brake Specific Fuel Power
CSC	Closed and Semi-closed Environments (e.g., enclosed storage area in which material handling equipment must operate)
CFR	Code of Federal Regulations
DACS	Defense Ammunition Center and School
DARCOM	U.S. Army Material Development and Readiness Command
DDR	German Democratic Republic
DIN	Deutches Industrie Norm
EPA	Environmental Protection Agency
FRG	Federal Republic of Germany
gm	Grams
OSP	British standards, International Standards Organization
IUC	International Union of Chemistry
MEC	Maximum Emission Concentration
MERADCOM	U.S. Army Mobility Equipment Research and Development Laboratories, Fort Belvoir, VA (a component of DARCOM)

APPENDIX A
GLOSSARY (Cont.)

MTBF	Mean Time Before Failure
MTBO	Mean Time Between Overhauls
MTTR	Mean Time to Repair
NIOSH	National Institute of Occupational Safety and Hea
PCC	Precombustion Chamber
PIT	Population Identification Threshold
POL	Provisional Operational Limit
PPM	Parts per Million
RE/CBDE	Reduced Emission/Clean Burning-Diesel Engines
ROC	Required Operational Capability (a formal statement of an Army need)
SAI	Science Applications, Inc. (this effort performed by SAI office in McLean, VA)
SAE	Society of Automotive Engineers
TOC	Threshold Odor Concentration
TRADOC	U.S. Army Training and Doctrine Command
TSP	Total Suspended Particulates
TWA	Time-Weighted Averages

APPENDIX B
EXTRACTS OF NATIONAL FIRE CODES

Chapter 5. Special Occupancies

ARTICLE 500 – HAZARDOUS (CLASSIFIED) LOCATIONS

500-1. Scope — Articles 500 Through 503. Articles 500 through 503 cover the requirements for electrical equipment and wiring for all voltages in locations where fire or explosion hazards may exist.

Locations are classified depending on the properties of the flammable vapors, liquids or gases, or combustible dusts or fibers which may be present and the likelihood that a flammable or combustible concentration or quantity is present.

Each room, section or area shall be considered individually in determining its classification.

Exception: Except as modified in Articles 500 through 503, all other applicable rules contained in this Code shall apply to electric equipment and wiring installed in hazardous locations.

For defintions of "approved" and "explosion-proof" as used in these articles, see Article 100; "dust-ignition-proof" is defined in Section 502-1.

Equipment and associated wiring approved as intrinsically safe shall be permitted in any hazardous (classified) location for which it is approved, and the provisions or Articles 500 through 517 shall not be considered applicable to such installations. Means shall be provided to prevent the passage of gases and vapors. Intrinsically safe equipment and wiring shall not be capable of releasing sufficient electrical or thermal energy under normal or abnormal conditions to cause ignition of a specific hazardous atmospheric mixture in its most easily ignited concentration.

Abnormal conditions shall include accidental damage to any field-installed wiring, failure of electrical components, application of overvoltage, adjustment and maintenance operations, and other similar conditions.

For further information, see Intrinsically Safe Process Control Equipment for Use in Class I Hazardous Locations (NFPA No. 493-1975).

Through the exercise of ingenuity in the layout of electrical installations for hazardous locations, it is frequently possible to locate much of the equipment in less hazardous or in nonhazardous locations and thus to reduce the amount of special equipment required. In some cases, hazards may be reduced or hazardous locations limited or eliminated by adequate positive-pressure ventilation from a source of clean air in conjunction with effective safeguards against ventilation failure. For further information see Purged and Pressurized Enclosures for Electrical Equipment in Hazardous Locations NFPA 496-1974 (ANSI).

It is important that the authority having jurisdiction be familiar with such recorded industrial experience as well as with such standards of the National Fire Protection Association as may be of use in the classification of various areas with respect to hazard.

For further information, see Hazardous Locations Classification (NFPA No. 70C-1974).

For further information, see Flammable and Combustible Liquids Code NFPA

30-1976 (ANSI); Dry Cleaning Plants NFPA 32-1974 (ANSI); Manufacture of Organic Coatings NFPA 35-1976 (ANSI); Solvent Extraction Plants NFPA 36-1974 (ANSI); Storage and Handling of Liquefied Petroleum Gases NFPA 58-1976 (ANSI); Storage and Handling of Liquefied Petroleum Gases at Utility Gas Plants NFPA 59-1976 (ANSI); and Classification of Class I Hazardous Locations for Electrical Installations in Chemical Plants NFPA 497-1975 (ANSI).

For protection against static electricity hazards, see Recommended Practice on Static Electricity (NFPA 77-1972).

All conduit referred to herein shall be threaded with a NPT standard conduit cutting die that provides ¾-inch taper per foot. Such conduit shall be made up wrench-tight to minimize sparking when fault current flows through the conduit system. Where it is impractical to make a threaded joint tight, a bonding jumper shall be utilized.

500-2. Special Precaution. Article 500 through 503 require a form of construction of equipment and of installation that will ensure safe performance under conditions of proper use and maintenance.

It is important that inspection authorities and users exercise more than ordinary care with regard to installation and maintenance.

The explosion characteristics of air mixtures of hazardous gases, vapors, or dusts vary with the specific material involved. For Class I locations, Group A, B, C, and D, the classification involves determinations of maximum explosion pressure, maximum safe clearance between parts of a clamped joint in an enclosure, and the minimum ignition temperature of the atmospheric mixture. For Class II locations, Groups E, F, and G, the classification involves the tightness of the joints of assembly and shaft openings to prevent entrance of dust in the dust-ignition-proof enclosure, *the blanketing effect of layers of dust on the equipment that may cause overheating,* electrical conductivity of the dust, and the ignition temperature of the dust. It is necessary, therefore, that equipment be approved not only for the class, but also for the specific group of the gas, vapor, or dust that will be present.

For purposes of testing and approval, various air mixtures (not oxygen-enriched) have been grouped on the basis of their hazardous characteristics and facilities have been made available for testing and approving equipment for use in the following atmospheric groups:

For Groups A, B, C, and D, see Table 500-2.

Group E: Atmospheres containing metal dust, including aluminum, magnesium, and their commercial alloys, and other metals of similarly hazardous characteristics.

Group F: Atmospheres containing carbon black, charcoal, coal or coke dusts which have more than 8 percent total volatile material (carbon black per ASTM D1620, charcoal, coal and coke dusts per ASTM D271) or atmospheres containing these dusts sensitized by other materials so that they present an explosion hazard.

Group G: Atmospheres containing flour, starch, or grain dust.

1. Certain chemical atmospheres may have characteristics that require safeguards beyond those required for any of the above groups. Carbon disulfide is one of these chemicals because of its low ignition temperature, 100°C (212°F), and the small joint clearance to arrest its flame.

2. Certain metal dusts may have characteristics that require safeguards beyond those required for atmospheres containing the dusts of aluminum, magnesium, and their commercial alloys. For example, zirconium, thorium and uranium dusts have extremely low ignition temperatures [as low as 20°C (68°F)], and minimum ignition energies lower than any material classified in any of the Class I or Class II Groups.

For a complete list noting properties of flammable liquids, gases and solids, see *Fire-Hazard Properties of Flammable Liquids, Gases, Volatile Solids* (NFPA No. 325M-1969).

(a) Approval for Class and Properties. Equipment shall be approved

not only for the class of location but also for the explosion properties of the specific gas, vapor, or dust that will be present. In addition, equipment shall not have exposed any surface that operates at a temperature in excess of the ignition temperature of the specific gas, vapor, or dust.

Equipment that has been approved for a Division I location shall be permitted in a Division 2 location of the same class and group.

Where specifically permitted in Articles 501 through 503, general-purpose equipment or equipment in general-purpose enclosures shall be permitted to be installed in Division 2 locations if the equipment does not constitute a source of ignition under normal operating conditions.

The characteristics of various atmospheric mixtures of hazardous gases, vapors, and dusts depend on the specific hazardous material involved.

(b) Marking. Approved equipment shall be marked to show the Class, Group, and operating temperature, or temperature range, based on operation in a 40°C ambient, for which it is approved.

The temperature range, if provided, shall be indicated in identification numbers, as shown in Table 500-2(b).

Identification numbers marked on equipment nameplates shall be in accordance with Table 500-2(b).

Exception No. 1: Equipment of the nonheat-producing type, such as junction boxes, conduit, and fittings and equipment of the heat producing type having a maximum temperature not more than 100°C (212°F), shall not be required to have a marked operating temperature or temperature range.

Exception No. 2: Fixed lighting fixtures marked for use in Class I, Division 2 locations only, need not be marked to indicate the Group.

Exception No. 3: Fixed general-purpose equipment, other than fixed lighting fixtures, which is acceptable for use in Division 2 locations shall not be required to be marked with the Class, Group, Division or operating temperature.

For purposes of testing and approval, various atmospheric mixtures (not oxygen-enriched) have been grouped on the basis of their hazardous characteristics, and facilities have been made available for testing and approving equipment for use in the atmospheric groups listed in Table 500-2. Since there is no consistent relationship between explosion properties and ignition temperature, the two are independent requirements.

(c) Temperature. The temperature marking specified in (b) above shall not exceed the ignition temperature of the specific gas or vapor to be encountered.

For information regarding ignition temperatures of gases and vapors, see Fire-Hazard Properties of Flammable Liquids, Gases, Volatile Solids (NFPA No. 325M-1969).

Formerly the temperature limit of each Group was assumed to be the lowest ignition temperature of any material in the Group, i.e., 280°C for Group D, 180°C for Group C.

To avoid revising this limit as new gases are added (see hexane in Group D and acetaldehyde in Group C), temperature will be specified in future markings.

The ignition temperature for which equipment was approved prior to this requirement shall be assumed to be as follows:

Group A 280°C (536°F)	Group C 180°C (356°F)
Group B 280°C (536°F)	Group D 280°C (536°F)

Maximum surface temperatures for equipment in Class II hazardous locations are covered in Section 502-1.

Table 500-2. Chemicals by Groups

Group A Atmospheres

Chemical
acetylene

Group B Atmospheres

Chemical
acrolein (inhibited)[2]
butadiene[1]
ethylene oxide[2]
hydrogen
manufactured gases containing more than 30% hydrogen (by volume)
propylene oxide[2]

Group C Atmospheres

Chemical
acetaldehyde
allyl alcohol
n-butyraldehyde
carbon monoxide
crotonaldehyde
cyclopropane
diethyl ether
diethylamine
epichlorohydrin
ethylene
ethylenimine
hydrogen sulfide
morpholine
2-nitropropane
tetrahydrofuran
unsymmetrical dimethyl hydrazine (UDMH 1, 1-dimethyl hydrazine)

Group D Atmospheres

Chemical
acetic acid (glacial)
acetone
acrylonitrile
ammonia[3]
benzene
butane
1-butanol (butyl alcohol)
2-butanol (secondary butyl alcohol)
n-butyl acetate
isobutyl acetate
sec-butyl alcohol
di-isobutylene
ethane
ethanol (ethyl alcohol)
ethyl acetate
ethyl acrylate (inhibited)
ethylene diamine (anhydrous)
ethylene dichloride
gasoline
heptanes
hexanes
isoprene
isopropyl ether
mesityl oxide
methane (natural gas)
methanol (methyl alcohol)
3-methyl-1-butanol (isoamyl alcohol)
methyl ethyl ketone
methyl isobutyl ketone
2-methyl-1-propanol (isobutyl alcohol)
2-methyl-2-propanol (tertiary butyl alcohol)
petroleum naphtha[4]
pyridine
octanes
pentanes
1-pentanol (amyl alcohol)
propane
1-propanol (propyl alcohol)
2-propanol (isopropyl alcohol)
propylene
styrene
toluene
vinyl acetate
vinyl chloride
xylenes

[1] Group D equipment shall be permitted for this atmosphere if such equipment is isolated in accordance with Section 501-5(a) by sealing all conduit ½-inch size or larger.

[2] Group C equipment shall be permitted for this atmosphere if such equipment is isolated in accordance with Section 501-5(a) by sealing all conduit ½-inch size or larger.

[3] For classification of areas involving ammonia atmosphere, see Safety Code for Mechanical Refrigeration (ANSI B9.1-1971) and Safety Requirements for the Storage and Handling of Anhydrous Ammonia (ANSI K61.1-1972).

[4] A saturated hydrocarbon mixture boiling in the range 20-135°C (68-275°F). Also known by the synonyms benzine, ligroin, petroleum ether, or naphtha.

Table 500-2(b). Identification Numbers

Maximum Temperature Degrees C	Degrees F	Identification Number
450	842	T1
300	572	T2
280	536	T2A
260	500	T2B
230	446	T2C
215	419	T2D
200	392	T3
180	356	T3A
165	329	T3B
160	320	T3C
135	275	T4
120	248	T4A
100	212	T5
85	185	T6

500-3. Specific Occupancies. Articles 510 through 517 cover garages, aircraft hangars, gasoline dispensing and service stations, bulk storage plants, finishing processes, and health care facilities.

500-4. Class I Locations. Class I locations are those in which flammable gases or vapors are or may be present in the air in quantities sufficient to produce explosive or ignitible mixtures. Class I locations shall include those specified in (a) and (b) below.

(a) Class I, Division 1. A Class I, Division 1 location is a location: (1) in which hazardous concentrations of flammable gases or vapors exist continuously, intermittently, or periodically under normal operating conditions; or (2) in which hazardous concentrations of such gases or vapors may exist frequently because of repair or maintenance operations or because of leakage; or (3) in which breakdown or faulty operation of equipment or processes might release hazardous concentrations of flammable gases or vapors, and might also cause simultaneous failure of electric equipment.

This classification usually includes locations where volatile flammable liquids or liquefied flammable gases are transferred from one container to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used; locations containing open tanks or vats of volatile flammable liquids; drying rooms or compartments for the evaporation of flammable solvents; locations containing fat and oil extraction equipment using volatile flammable solvents; portions of cleaning and dyeing plants where hazardous liquids are used, gas generator rooms and other portions of gas manufacturing plants where flammable gas may escape; inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids; the interiors of refrigerators and freezers in which volatile flammable materials are stored in open, lightly stoppered, or easily ruptured containers; and all other locations where hazardous concentrations of flammable vapors or gases are likely to occur in the course of normal operations.

(b) Class I, Division 2. A Class I, Division 2 location is a location: (1) in which volatile flammable liquids or flammable gases are handled, processed, or used, but in which the hazardous liquids, vapors, or gases will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; or (2) in which hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation, and which might become hazardous through failure or abnormal operation of the ventilating equipment; or (3) that is adjacent to a Class I, Division 1 location, and to which hazardous concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.

This classification usually includes locations where volatile flammable liquids or flammable gases or vapors are used, but which, in the judgment of the authority having jurisdiction, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of hazardous material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that merit consideration in determining the classification and extent of each location.

Piping without valves, checks, meters, and similar devices would not ordinarily introduce a hazardous condition even though used for hazardous liquids or gases. Locations used for the storage of hazardous liquids or of liquefied or compressed gases in sealed containers would *not normally be considered* hazardous unless subject to other hazardous conditions also.

Electrical conduits and their associated enclosures separated from process fluids by a single seal or barrier shall be classed as a Division 2 location if the outside of the conduit and enclosures is a nonhazardous location.

500-5. Class II Locations. Class II locations are those that are hazardous because of the presence of combustible dust. Class II locations shall include those specified in (a) and (b) below.

(a) Class II, Division 1. A Class II, Division 1 location is a location: (1) in which combustible dust is or may be in suspension in the air continuously, intermittently, or periodically under normal operating conditions, in quantities sufficient to produce explosive or ignitible mixtures; or (2) where mechanical failure or abnormal operation of machinery or equipment might cause such explosive or ignitible mixtures to be produced, and might also provide a source of ignition through simultaneous failure of electric equipment, operation of protection devices, or from other causes; or (3) in which combustible dusts of an electrically conductive nature may be present.

This classification usually includes the working areas of grain handling and storage plants; rooms containing grinders or pulverizers, cleaners, graders, scalpers, open conveyors or spouts, open bins or hoppers, mixers or blenders, automatic or hopper scales, packing machinery, elevator heads and boots, stock distributors, dust and stock collectors (except all-metal collectors vented to the outside), and all similar dust-producing machinery and equipment in grain-processing plants, starch plants, sugar-pulverizing plants, malting plants, hay-grinding plants, and other occupancies of similar nature; coal-pulverizing plants (except where the pulverizing equipment is essentially dust-tight); all working areas where metal dusts and powders are produced, processed, handled, packed, or stored (except in tight containers); and all other similar locations where combustible dust may, under normal

operating conditions, be present in the air in quantities sufficient to produce explosive or ignitible mixtures.

Combustible dusts which are electrically nonconductive include dusts produced in the handling and processing of grain and grain products, pulverized sugar and cocoa, dried egg and milk powders, pulverized spices, starch and pastes, potato and woodflour, oil meal from beans and seed, dried hay, and other organic materials which may produce combustible dusts when processed or handled. Electrically conductive nonmetallic dusts include dusts from pulverized coal, coke, carbon black, and charcoal. Dusts containing magnesium or aluminum are particularly hazardous and the use of extreme precaution will be necessary to avoid ignition and explosion.

(b) Class II, Division 2. A Class II, Division 2 location is a location in which combustible dust will not normally be in suspension in the air or will not be likely to be thrown into suspension by the normal operation of equipment or apparatus in quantities sufficient to produce explosive or ignitible mixtures, but: (1) where deposits or accumulations of such combustible dust may be sufficient to interfere with the safe dissipation of heat from electric equipment or apparatus; or (2) where such deposits or accumulations of combustible dust on, in, or in the vicinity of electric equipment might be ignited by arcs, sparks, or burning material from such equipment.

Locations where dangerous concentrations of suspended dust would not be likely, but where dust accumulations might form on, or in the vicinity of electric equipment, would include rooms and areas containing only closed spouting and conveyors, closed bins or hoppers, or machines and equipment from which appreciable quantities of dust would escape only under abnormal operating conditions; rooms or areas adjacent to a Class II, Division 1 location as described in (a) above, and into which explosive or ignitible concentrations of suspended dust might be communicated only under abnormal operating conditions; rooms or areas where the formation of explosive or ignitible concentrations of suspended dust is prevented by the operation of effective dust control equipment; warehouses and shipping rooms where dust-producing materials are stored or handled only in bags or containers; and other similar locations.

500-6. Class III Locations. Class III locations are those that are hazardous because of the presence of easily ignitible fibers or flyings, but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitible mixtures. Class III locations shall include those specified in (a) and (b) below.

(a) Class III, Division 1. A Class III, Division 1 location is a location in which easily ignitible fibers or materials producing combustible flyings are handled, manufactured, or used.

Such locations usually include some parts of rayon, cotton, and other textile mills; combustible fiber manufacturing and processing plants; cotton gins and cotton-seed mills; flax-processing plants; clothing manufacturing plants; woodworking plants; and establishments and industries involving similar hazardous processes or conditions.

Easily ignitible fibers and flyings include rayon, cotton (including cotton linters and cotton waste), sisal or henequen, istle, jute, hemp, tow, cocoa fiber, oakum, baled waste kapok, Spanish moss, excelsior, and other materials of similar nature.

(b) Class III, Division 2. A Class III, Division 2 location is a location in which easily ignitible fibers are stored or handled.

Exception: In process of manufacture.

Fire Safety Standard for

Powered Industrial Trucks

Including Type Designations and Areas of Use

NFPA No. 505 — 1973

Notice: An asterisk(*) following the number or letter designating a paragraph indicates explanatory material on that paragraph in Appendix A.

Chapter 1 Type Designations and Areas of Use

1-1 Scope. This standard applies to fork trucks, tractors, platform lift trucks, motorized hand trucks and other specialized industrial trucks powered by electric motors or internal combustion engines. This standard does not apply to compressed air or nonflammable compressed gas-operated industrial trucks, to farm vehicles, or to automotive vehicles for highway use.

1-2 General.

1-2.1 Design and installation of the LP-Gas fuel systems on LP-Gas powered industrial trucks shall be in accordance with the applicable provisions of the *Standard for the Storage and Handling of Liquefied Petroleum Gas, NFPA No. 58-1972; ANSI Z106.1-1972.*

1-2.2 Approved powered industrial trucks as used in this standard are those trucks listed for the use intended, by a nationally recognized testing laboratory. Trucks shall bear a label or some other identifying mark to that effect authorized by such laboratory. The word "listed" herein shall mean compliance with the above.

To prevent confusion all testing laboratories shall use the same type designations to identify the various types of industrial trucks.

1-3* Type Designations. For the purpose of this standard there are eleven different type designations of industrial trucks or tractors as follows:

(a) The *type D* units are diesel powered units having minimal acceptable safeguards against inherent fire hazards.

(b) The *type DS* units are diesel powered units that, in addition to all the requirements for the type D units, are provided with

additional safeguards to the exhaust, fuel and electrical systems.

(c) The *type DY* units are diesel powered units that have all the safeguards of the type DS units, and in addition, do not have any electrical equipment, including ignition. They are equipped with temperature limitation features.

(d) The *type E* units are electrically powered units having minimum acceptable safeguards against inherent fire and electrical shock hazards.

(e) The *type ES* units are electrically powered units that, in addition to all of the requirements for the type E units, are provided with additional safeguards to the electrical system to prevent emission of hazardous sparks and to limit surface temperatures.

(f) The *type EE* units are electrically powered units that have, in addition to all of the requirements for the types E and ES units, the electric motors and all other electrical equipment completely enclosed.

(g) The *type EX* units are electrically powered units that differ from the types E, ES or EE units in that the electrical fittings and equipment are so designed, constructed and assembled that the units may be used in atmospheres containing specifically named flammable vapors, dusts, and, under certain conditions, fibers. Type EX units are specifically tested and classified for use in Class I, Group D or for Class II, Group G hazardous locations as defined in the *National Electrical Code, NFPA No. 70-1971; ANSI C1-1971.*

(h) The *type G* units are gasoline powered units having minimum acceptable safeguards against inherent fire hazards.

(i) The *type GS* units are gasoline powered units that, in addition to all the requirements for the type G units, are provided with additional safeguards to the exhaust, fuel and electrical systems.

(j) The *type LP* units are liquefied petroleum gas powered units having minimum acceptable safeguards against inherent fire hazards.

(k) The *type LPS* units are liquefied petroleum gas powered units that, in addition to the requirements for the type LP units, are provided with additional safeguards to the exhaust, fuel and electrical systems.

1-4 The authority having jurisdiction shall determine the hazard classification of any particular atmosphere or location. The atmosphere or location shall have been classified as to whether it is hazardous or nonhazardous prior to the consideration of industrial trucks being used therein and the type of industrial truck required shall be as provided in Section 1-7 of this standard for such location.

Table 1-7 — Summary Table on Use of Powered Industrial Trucks as Described in Chapter 1 of this Standard

	Diesel-Powered			Electric-Powered				Gasoline-Powered		LP-Gas-Powered		Text Par.
Locations	D	DS	DY	E	ES	EE	EX	G	GS	LP	LPS	Reference
Class I Division 1												
Group A												1-7.1
Group B												1-7.1
Group C												1-7.1
Group D							A					1-7.2
Class I Division 2												
Group A		X	X		X	X	X		X		X	1-7.9
Group B		X	X		X	X	X		X		X	1-7.9
Group C		X	X		X	X	X		X		X	1-7.9
Group D		A*	A		A*	A	A		A*		A*	1-7.3
Class II Division 1												
Group E							A*					1-7.4
Group F							A*					1-7.4
Group G							A					1-7.5
Class II Division 2												
Group E		X	X		X	X	X		X		X	1-7.9
Group F		X	X		X	X	X		X		X	1-7.9
Group G		A*	A		A*	A	A		A*		A*	1-7.6
Class III Division 1			A			A	A					1-7.7
Class III Division 2		A	A	A*	A	A	A		A		A	1-7.8

Key To Table Symbols

A = Type truck authorized in location described.
A* = Type truck authorized in location described with approval of the authority having jurisdiction.
X = Type truck authorized to be determined by the authority having jurisdiction.
Blank spaces = Type truck not authorized in location described.

1-5 Several areas of any one plant or building occasionally have different hazard classifications. The authority having jurisdiction shall limit the use of industrial trucks in hazardous areas in a plant or building in accordance with the hazard classification of such areas. The responsibility for enforcement of restricted use in such areas shall rest on management.

1-6 The industrial trucks specified in Section 1-7 are the minimum types required. Industrial trucks having greater safeguards may be used if desired.

1-7 Specific Areas of Use.

NOTE: Table I provides a summary of industrial truck types for specific areas of use and was developed from *information contained in this section.*

References in parentheses in the following subsection headings in this Section are to the corresponding classification as used in the *National Electrical Code, NFPA No. 70–1971; ANSI C1 1971* for the convenience of people familiar with those classifications.

1-7.1 Areas Containing Certain Flammable Gases or Vapors Where Power-Operated Industrial Trucks Shall Not Be Used (Class I, Groups A, B and C, Division 1). Power-operated industrial trucks shall not be used in atmospheres containing hazardous concentrations of acetylene, butadiene, ethylene oxide, hydrogen, manufactured gases containing more than 30 percent hydrogen (by volume), propylene oxide, acetaldehyde, cyclopropane, diethyl ether, ethylene, isoprene, or unsymmetrical dimethyl hydrazine (UDMH).

1-7.2 Atmospheres Where Vapors of Flammable Liquids and Some Gases Exist Under Normal Operating Conditions (Class I, Group D, Division 1).

1-7.2.1 Approved power-operated industrial trucks designated as type EX and classified for Class I, Group D hazardous locations shall be used in atmospheres containing vapors of such flammable liquids or gases as: acetone, acrylonitrile, benzene, butane, ethylene dichloride, gasoline, hexanes, methane, propane, propylene, styrene, vinyl acetate, vinyl chloride, or xylenes in quantities sufficient to produce explosive or ignitible mixtures and where such concentrations of these gases or vapors exist continuously, intermittently or periodically under normal operating conditions or might exist frequently because of repair, maintenance operations, leakage, breakdowns or faulty operation of equipment.

NOTE: For a listing of chemicals of which mixtures of their vapors in air are classified as Class I, Group D, see Table 500 2(c) of the *National Electrical Code, NFPA No. 70 1971; ANSI C1 1971.*

1-7.2.2 Class I, Group D, Division 1 includes locations where volatile flammable liquids or liquefied flammable gases are transferred from one container to another; interiors of spray booths and areas in the vicinity of spraying and painting operations where volatile flammable solvents are used; locations containing open tanks or vats of volatile flammable liquids; drying rooms or compartments for the evaporation of flammable solvents; locations containing fat and oil extraction apparatus using volatile flammable solvents; portions of cleaning and dyeing plants where hazardous liquids are used; gas generator rooms and other portions of gas manufacturing plants where flammable gas may escape; inadequately ventilated pump rooms for flammable gas or for volatile flammable liquids; the interiors of refrigerators and freezers in which volatile flammable materials are stored in open, lightly stoppered, or easily ruptured containers; and all other locations where hazardous concentrations of flammable vapors or gases are likely to occur in the course of normal operations.

1-7.3 Atmospheres Where Volatile Flammable Liquids and Their Vapors or *Flammable Gases Are Normally* Confined (Class I, Group D, Division 2).

1-7.3.1 Approved power-operated industrial trucks designated as types DY, EE or EX (classified for Class I, Group D hazardous locations) shall be used in locations where volatile flammable liquids or flammable gases are handled, processed or used, but in which the hazardous liquids, vapors or gases will normally be confined within closed containers or closed systems from which they might escape only in case of accidental rupture or breakdown of such containers or systems, or in case of abnormal operation of equipment; also in locations in which hazardous concentrations of gases or vapors are normally prevented by positive mechanical ventilation but which might become hazardous through failure or abnormal operation of the ventilating equipment; or in locations which are adjacent to Class I, Division 1 locations, and to which hazardous concentrations of gases or vapors might occasionally be communicated unless such communication is prevented by adequate positive-pressure ventilation from a source of clean air, and effective safeguards against ventilation failure are provided.

1-7.3.2 In locations used for the storage of hazardous liquids in sealed containers or liquefied or compressed flammable gases in containers, approved power-operated industrial trucks designated as types DS, ES, GS or LPS may be used if permitted for such location by the authority having jurisdiction.

1-7.3.3 The classification Class I, Group D, Division 2 includes locations where volatile flammable liquids or flammable gases or vapors are used, but which, in the judgment of the authority having jurisdiction, would become hazardous only in case of an accident or of some unusual operating condition. The quantity of hazardous material that might escape in case of accident, the adequacy of ventilating equipment, the total area involved, and the record of the industry or business with respect to explosions or fires are all factors that should receive consideration in determining whether or not the DS, DY, ES, EE, GS, LPS type truck possesses sufficient safeguards for the location.

1-7.4 Atmospheres Containing Metal Dusts, Carbon Black, Coke or Coal Dust (Class II, Groups E and F, Division 1).

1-7.4.1 Power-operated industrial trucks shall not be used in atmospheres containing hazardous concentrations of metal dust, including aluminum, magnesium, and their commercial alloys, other metals of similarly hazardous characteristics, or in atmospheres containing carbon black, coal or coke dust.

Exception: Approved power-operated industrial trucks designated as type EX may be used in such atmospheres subject to special investigation by the authority having jurisdiction.

1-7.4.2 In atmospheres where dust of magnesium, aluminum or aluminum bronze might be present, fuses, switches, motor controllers and circuit breakers of trucks shall have enclosures specifically approved for such locations.

1-7.5 Atmospheres Containing Combustible Dusts in Suspension Other Than Those Specified in 1-7.4 (Class II, Group G, Division 1).

1-7.5.1 Approved power-operated industrial trucks designated as EX (classified for Class II, Group G, hazardous locations) shall be used in atmospheres in which combustible dust is or may be in suspension continuously, intermittently or periodically under normal operating conditions, in quantities sufficient to produce explosive or ignitible mixtures, or where mechanical failure or abnormal operation of machinery or equipment might cause such mixtures to be produced.

1-7.5.2 The classification Class II, Group G, Division 1 includes the working areas of grain handling and storage plants, rooms containing grinders or pulverizers, cleaners, graders, scalpers, open conveyors or spouts, open bins or hoppers, mixers or blenders, automatic or hopper scales, packing machinery, elevator heads and boots, stock distributors, dust and stock collectors (except all-

metal collectors vented to the outside), and all similar dust producing machinery and equipment in grain processing plants, starch plants, sugar pulverizing plants, malting plants, hay grinding plants, and other occupancies of similar nature where combustible dust might, under normal operating conditions, be present in the air in quantities sufficient to produce explosive or ignitible mixtures.

1-7.6 Locations Where Combustible Dusts Are Present But Not Normally in Suspension in the Atmosphere (Class II, Group G, Division 2).

1-7.6.1 Approved power-operated industrial trucks designated as type DY, EE or EX (classified for Class II, Group G hazardous locations) shall be used in atmospheres in which combustible dust is not normally in suspension in the air or is not likely to be thrown into suspension by the normal operation of equipment or apparatus in quantities sufficient to produce explosive or ignitible mixtures but where deposits or accumulations of such dust might be ignited by arcs or sparks originating in the truck.

1-7.6.2 In locations where dangerous concentrations of suspended dust would not be likely, approved power-operated industrial trucks designated as types DS, ES, GS or LPS may be used if permitted for such location by the authority having jurisdiction. These locations would include rooms and areas containing only closed spouting and conveyors, closed bins or hoppers, or machines and equipment from which appreciable quantities of dust would escape only under abnormal operating conditions; rooms or areas into which explosive or ignitible concentrations of suspended dust might be communicated only under abnormal operating conditions; rooms or areas where the formation of explosive or ignitible concentrations of suspended dust is prevented by the operation of effective dust control equipment; warehouses and shipping rooms where dust producing materials are stored or handled only in bags or containers and other similar locations.

1-7.7 Locations Where Ignitible Fibers Are Processed (Class III, Division 1).

1-7.7.1 Approved power-operated industrial trucks designated as types DY, EE or EX shall be used in locations which are hazardous because of the presence of easily ignitible fibers or flyings but in which such fibers or flyings are not likely to be in suspension in the air in quantities sufficient to produce ignitible mixtures.

1-7.7.2 Locations where easily ignitible fibers or flyings are found usually include some parts of rayon, cotton, and other textile mills; combustible fiber manufacturing and processing plants;

cotton gins and cotton-seed mills; flax processing plants; clothing manufacturing plants; and establishments and industries involving similar hazardous processes or conditions. Woodworking plants (except wood flour mills) shall not be considered as being in the type of locations defined in 1-7.7.

1-7.8 Locations Where Ignitible Fibers Are Stored (Class III, Division 2).

1-7.8.1 Approved power-operated industrial trucks designated as types DS, DY, ES, EE, EX, GS or LPS shall be used in locations where easily ignitible fibers are stored or handled, including outside storage, but are not being processed or manufactured. Industrial trucks designated as type E, which have been previously used in these locations may be continued in use with the approval of the authority having jurisdiction.

1-7.8.2 Easily ignitible fibers and flyings include rayon, cotton (including cotton linters and cotton waste), sisal or henequen, istle, jute, hemp, tow, cocoa fiber, oakum, baled waste kapok, Spanish moss, excelsior, and other materials of similar nature.

1-7.9 Hazardous Locations Not Otherwise Classified. The authority having jurisdiction shall determine what types of power-operated industrial truck, if any, shall be used based on an engineering survey of the property and an evaluation of the fire and explosion hazards.

1-7.10 Piers and Wharves.

1-7.10.1 When determined that the location on piers and wharves for handling general cargo is not hazardous, any approved power-operated industrial truck designated as type D, E, G, or LP may be used, or trucks which conform to the requirements for these types may be used.

1-7.10.2 Where an area of a pier or wharf is determined to be hazardous, only approved power-operated industrial trucks specified for such locations in the preceding subsections shall be used.

1-7.11 General Inside and Outside Storage.

1-7.11.1 When determined that the location for general storage in warehouses or general outside storage is not hazardous, any approved power-operated industrial truck designated as type D, E, G, or LP may be used or trucks which conform to the requirements for these types may be used.

1-7.11.2 Where the location for general storage in warehouses or general outside storage is determined to be hazardous, only approved power-operated industrial trucks specified for such locations in the preceding subsections shall be used.

1-7.12 General Industrial or Commercial Properties.

1-7.12.1 When determined that the location on general industrial or commercial properties for handling or processing materials (storage being incidental to handling and processing), or both is not hazardous, any approved power-operated industrial truck designated as type D, E, G, or LP may be used, or trucks which conform to the requirements for these types may be used.

1-7.12.2 Where the location on general industrial or commercial properties for handling or processing materials, or both is determined to be hazardous, only approved power-operated industrial trucks specified for such locations in the preceding subsections shall be used.

1-7.13 Converted Industrial Trucks. Power-operated industrial trucks that have been originally approved for the use of gasoline for fuel and designated as type G or GS, when converted to the use of liquefied petroleum gas fuel in accordance with Chapter 2 (*see 2-8*), may be used in those locations where G, GS or LP and LPS type trucks have been specified in the preceding subsections.

3-3 Use of Trucks in Hazardous Areas.

3-3.1 Industrial trucks shall not be used in hazardous areas except as specified in Chapter 1 of this standard.

3-3.2 Markings of Types DS, DY, ES, EE, EX, GS and LPS Industrial Trucks and Areas of Use.

3-3.2.1 The use of proper equipment in hazardous areas is essential for the safety and protection of employees and property. Approved trucks, listed by a nationally recognized testing laboratory for use in such areas shall be clearly identified. To facilitate identification by both operators and supervisory personnel, a uniform system of marking has been developed as described herein.

3-3.2.2 Durable markers indicating the designation of type of truck shall be applied to each side of the vehicle in a visible but protected location. These markers are distinctive in shape as indicated in Figure 3-3.2.2.

3-3.2.3 Entrances to hazardous areas shall be posted with large durable markers of corresponding shape as shown in Figure 3-3.2.3.

3-3.2.4 Suitable markers may be obtained from NFPA, 470 Atlantic Avenue, Boston, Massachusetts 02210, at nominal prices.

3-4 Safe Operating Rules. This standard primarily concerns powered industrial truck fire safety. For safe operating rules, see the *American National Standard Safety Code for Powered Industrial Trucks, ANSI B56.1-1969.*

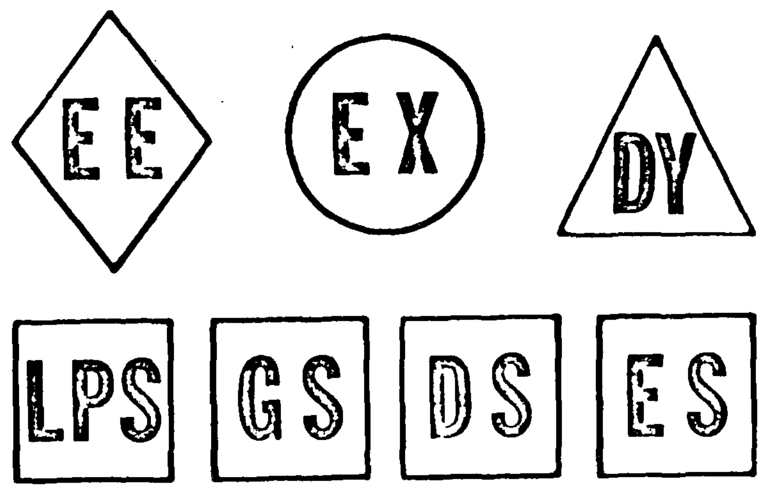


Figure 3-3.2.2 Markers to identify type of industrial truck. The markers for LPS, GS, DS, and ES are 4 inches square. The width of the others is 5 inches.

Figure 3-3.2.3 Building signs for posting at entrances to hazardous areas. The width of each is 11 inches. Building signs for Type DY and ES may be produced on demand.

Fire-Hazard Properties (of Substanced Identified in Diesel Engine Exhausts)

(Extract of National Fire Codes)

Substance	Ignition Temp. Deg. F	Flammability Limits % by Volume		Vapor Density (Air = 1)	Suggested Hazard Identification (See Notes)		
		Lower	Upper		Health	Flammability	Reactivity
Acetaldehyde CH_3CHO (Acetic Aldehyde) (Ethanal)	347	4.0	60	1.5	2	4	2
Acetone CH_3COCH_3 (Dimethyl Ketone) (2-Propanone)	869	2.6 2.40@ 212°F	12.8	2.0	1	3	0
Acetylene CH:CH (Ethine) (Ethyne)	581	2.5	100	0.9	1	4	3
Acrolein CH_2:CHCHO (Acrylic Aldehyde)	455 Unstable	2.8	31	1.9	3	3	2
Benzaldehyde C_6H_5CHO (Artificial Almond Oil) (Benzenecarbonal)	377			3.7	2	2	0
Benzol C_6H_6 (Benzene)	1040	1.3	7.1	2.8	2	3	0

Fire-Hazard Properties (of Substanced Identified in Diesel Engine Exhausts)

(Extract of National Fire Codes) (Continued)

Substance	Ignition Temp. Deg. F	Flammability Limits % by Volume Lower	Upper	Vapor Density (Air = 1)	Suggested Hazard Identification (See Notes) Health	Flammability	Reactivity
1, 3-Butadiene $CH_2:CHCH:CH_2$ (Erythrene)	788	2.0	12.0	1.9	2	4	2
Butane $CH_3CH_2CH_2CH_3$	761	1.9	8.5	2.0	1	4	0
1-Butene $CH_3CH_2CH:CH_2$ (α-Butylene)	725	1.6	10.0	1.9	1	4	0
(trans) 2-Butene $CH_3CH:CHCH_3$ (β-Butylene)	615	1.8	9.7	1.9	1	4	0
Butyraldehyde $CH_3(CH_2)_2CHO$ (Butanal) (Butyric Aldehyde)	446	2.5	12.5	2.5	2	3	1
Carbon Monoxide CO	1128	12.5	74	1.0	2	4	0
Crotonaldehyde $CH_3CH:CHCHO$ (2-Butenal) (Crotonic Aldehyde) (Propylene Aldehyde)	450	2.1	15.5	2.4	3	3	2

Fire-Hazard Properties (of Substanced Identified in Diesel Engine Exhausts)

(Extract of National Fire Codes) (Continued)

Substance	Ignition Temp. Deg. F	Flammability Limits % by Volume		Vapor Density (Air = 1)	Suggested Hazard Identification (See Notes)		
		Lower	Upper		Health	Flammability	Reactivity
2, 3-Dimethylbutane $(CH_3)_2CHCH(CH_3)_2$ (Diisopropyl)	788	1.2	7.0	3.0	1	3	0
2, 3-Dimethylpentane $CH_3CH(CH_3)CH$- $(CH_3)CH_2CH_3$	635	1.1	6.7	3.5	0	3	0
2, 4-Dimethylpentane $(CH_3)_2CHCH_2CH(CH_3)_2$				3.5	0	3	0
Ethane CH_3CH_3	959	3.0	12.5	1.0	1	4	0
Ethylbenzene $C_2H_5C_6H_5$ (Ethylbenzol) (Phenylethane)	810	1.0	6.7	3.7	2	3	0

Fire-Hazard Properties (of Substanced Identified in Diesel Engine Exhausts)

(Extract of National Fire Codes) (Continued)

Substance	Ignition Temp. Deg. F	Flammability Limits % by Volume		Vapor Density (Air = 1)	Suggested Hazard Identification (See Notes)		
		Lower	Upper		Health	Flammability	Reactivity
Ethylene $H_2C{:}CH_2$ (Ethene)	914	2.7	36.0	1.0	1	4	2
p-Ethyltoluene $CH_3C_6H_4C_2H_5$ (1-Methyl-4-Ethylbenzene)	887		4.15			2	0
Formaldehyde HCHO (Formalin) (Methylene Oxide)	806	7.0	73	1.0	2	4	0
Heptane $CH_3(CH_2)_5CH_3$	419	1.05	6.7	3.5	1	3	0
Hexanal $CH_3(CH_2)_4CHO$ (Caproaldehyde) (Hexaldehyde)				3.6	2	3	1
Hexane $CH_3(CH_2)_4CH_3$ (Hexyl Hydride)	437	1.1	7.5	3.0	1	3	0

Fire-Hazard Properties (of Substanced Identified in Diesel Engine Exhausts)

(Extract of National Fire Codes) (Continued)

Substance	Ignition Temp. Deg. F	Flammability Limits % by Volume		Vapor Density (Air = 1)	Suggested Hazard Identification (See Notes)		
		Lower	Upper		Health	Flammability	Reactivity
Isobutane $(CH_3)_3CH$ (2-Methylpropane)	860	1.8	8.4	2.0	1	4	0
Isobutyraldehyde $(CH_3)_2CHCHO$ (2-Methylpropanal)	490	1.6	10.6	2.5	2	3	1
Isopentane $(CH_3)_2CHCH_2CH_3$ (2-Methylbutane) (Ethyl Dimethyl Methane)	788	1.4	7.6		1	4	0
Methane CH_4 (Marsh Gas)	1004	5.0	15.0	0.6	1	4	0
Methylcyclohexane $CH_2(CH_2)_4CHCH_3$ (Cyclohexylmethane) (Hexahydroxytoluene)	482	1.2	6.7	3.4	2	3	0

Fire-Hazard Properties (of Substanced Identified in Diesel Engine Exhausts)

(Extract of National Fire Codes) (Continued)

Substance	Ignition Temp. Deg. F	Flammability Limits % by Volume		Vapor Density (Air = 1)	Suggested Hazard Identification (See Notes)		Reactivity
		Lower	Upper		Health	Flammability	
Methyl Isobutyl Ketone $CH_3COCH_2CH(CH_3)_2$ (Hexone) (4-Methyl-2-Pentanone)	860	1.4	7.5	3.5	2	3	0
2-Methylpentane $(CH_3)_2CH(CH_2)_2CH_3$	583	1.2	7.0	3.0	1	3	0
Methyl Propyl Ketone $CH_3COC_3H_7$ (2-Pentanone)	941	1.5	8.2	3.0	2	3	0
Nickel Carbonyl $Ni(CO)_4$		2		5.89		3	1
Niroethane $C_2H_5NO_2$	778	3.4		2.6	1	3	3
Nitromethane CH_3NO_2	785	7.3		2.1	1	3	4
Octane $CH_3(CH_2)_6CH_3$	428	1.0	6.5	3.9	0	3	0

Fire-Hazard Properties (of Substanced Identified in Diesel Engine Exhausts)

(Extract of National Fire Codes) (Continued)

Substance	Ignition Temp. Deg. F	Flammability Limits % by Volume		Vapor Density (Air = 1)	Suggested Hazard Identification (See Notes)		
		Lower	Upper		Health	Flammability	Reactivity
Pentane $CH_3(CH_2)_3CH_3$	500	1.5	7.8	2.5	1	4	0
β-Propiolactone $C_3H_4O_2$		2.9		2.5	0	2	0
Propylene $CH_2{:}CHCH_3$ (Propene)	860	2.0	11.1	1.5	1	4	1
Propyne $CH_3C{:}CH$ (Allylene) (Methylacetylene)		1.7		1.4	2	4	2
Toluol $C_6H_5CH_3$ (Methylbenzene) (Phenylmethane) (Toluene)	896	1.2	7.1	3.1	2	3	0
1, 2, 4-Trimethylbenzene $C_6H_3(CH_3)_3$ (Pseudocumene)	959			4.15	0	2	0

Fire-Hazard Properties (of Substanced Identified in Diesel Engine Exhausts)

(Extract of National Fire Codes) (Continued)

Substance	Ignition Temp. Deg. F	Flammability Limits % by Volume		Vapor Density (Air = 1)	Suggested Hazard Identification (See Notes)		
		Lower	Upper		Health	Flammability	Reactivity
1, 3, 5-Trimethylbenzene $C_6H_3(CH_3)_3$ (Mesitylene)	1022			4.15	0	2	0
2, 2, 4-Trimethylpentane $(CH_3)_3CCH_2CH(CH_3)_2$	779	1.1	6.0	3.9		3	0
m-Xylene $C_6H_4(CH_3)_2$ (1, 3-Dimethylbenzene)	986	1.1	7.0	3.7	2	3	0

NOTES

Ignition Temperature of a substance, whether solid, liquid, or gaseous, is the minimum temperature required to initiate or cause self-sustained combustion independently of the heating or heated element.

Flammable (Explosive) Limits. In the case of gases or vapors which form flammable mixtures with air or oxygen (gases and vapors may form flammable mixtures in atmospheres other than air or oxygen, as for example hydrogen in chlorine), there is a minimum concentration of vapor in air or oxygen below which propagation of flame does not occur on contact with a source of ignition. There is also a maximum proportion of vapor or gas in air above which propagation of flame does not occur. These boundary line mixtures of vapor or gas with air, which if ignited will just propagate flame, are known as the "lower and upper flammable or explosive limits," and are usually expressed in terms of percentage by volume of gas or vapor in air.

Vapor Density. Vapor density is the weight of a volume of pure vapor or gas (with no air present) compared to the weight of an equal volume of dry air at the same temperature and pressure. It is calculated as the ratio of the molecular weight of the gas to the average

molecular weight of air, 29. A vapor density figure less than 1 indicates that the vapor is lighter than air and will tend to rise in a relatively calm atmosphere. A figure greater than 1 indicates that the vapor is heavier than air and may travel at low levels for a considerable distance to a source of ignition and flash back (if the vapor is flammable).

Suggested Hazard Identification

This system identifies the hazards of a material in terms of three categories; namely, "Health," "Flammability," and "Reactivity" and indicates the order of severity in each of these categories by five divisons ranging from "four (4)" indicating a severe hazard to "zero (0)" indicating no special hazard. The three categories were selected after studying approximately 35 inherent and environmental hazards of materials which could affect fire fighting operations. The five degrees were decided upon as necessary to give the required information. It was also felt that for such a system to be effective it had to be relatively simple and readily understood.

While this system is basically simple in application, the hazard evaluation which is required for the precise use of the signals in a specific location must be made by experienced, technically competent persons. Their judgment must be based on factors encompassing a knowledge of the inherent hazards of different materials, including the extent of change in behavior to be anticipated under conditions of fire exposure and control.

Degrees of Hazard

The columns under "Suggested Hazard Identification" in the listing of materials give the degrees of hazard severity for each category where information was available.

The following discussions on degrees of hazard are an interpretation of the information contained within NFPA No. 704M and are related specifically to the fire fighting aspects. Refer to NFPA No. 704M for a detailed discussion of the identification system.

Health

In general, health hazard in fire fighting is that of a single exposure which may vary from a few seconds up to an hour. The physical exertion demanded in fire fighting or other emergency conditions may be expected to intensify the effects of any exposure. Only hazards arising out of an inherent property of the material are considered. The following explanation is based upon protective equipment normally used by fire fighters.

4 Materials too dangerous to health to expose fire fighters. A few whiffs of the vapor could cause death or the vapor or liquid could be fatal on penetrating the fire fighter's normal full-protective clothing. The normal full-protective clothing and breathing apparatus available to the average fire department will not provide adequate protection against inhalation or skin contact with these materials.

3 Materials extremely hazardous to health, but areas may be entered with extreme care. Full protective clothing, including self-contained breathing apparatus, coat, pants, gloves, boots, and bands around legs, arms and waist should be provided. No skin surface should be exposed.

2 Materials hazardous to health, but areas may be entered freely with full-faced mask self-contained breathing apparatus which provides eye protection.

1 Materials only slightly hazardous to health. It may be desirable to wear self-contained breathing apparatus.

0 Materials which, on exposure under fire conditions, would offer no hazard beyond that of ordinary combustible material.

Flammability

Susceptibility to burning is the basis for assigning degrees within this category. The method of attacking the fire is influenced by this susceptibility factor. For further information on this subject, refer to the column on "Extinguishing Method" and to its explanation on pages 7-10.

4 Very flammable gases or very volatile flammable liquids. Shut off flow and keep cooling water streams on exposed tanks or containers.

3 Materials which can be ignited under almost all normal temperaure conditions. Water may be ineffective because of the low flash point.

2 Materials which must be moderately heated before ignition will occur. Water spray may be used to extinguish the fire, because the material can be cooled below its flash point.

1 Materials that must be preheated before ignition can occur. Water may cause frothing if it gets below the surface of the liquid and turns to steam. However, water fog gently applied to the surface will cause a frothing which will extinguish the fire.

0 Materials that will not burn.

Reactivity (Stability)

The assignment of degrees in the reactivity category is based upon the susceptibility of materials to release energy either by themselves or in combination with water. Fire exposure was one of the factors considered along with conditions of shock and pressure.

4 Materials which (in themselves) are readily capable of detonation or of explosive decomposition or exlosive reaction at normal temperatures and pressures. Includes materials which are sensitive to methanical or localized thermal shock. If a chemical with this hazard rating is in an advanced or massive fire, the area should be evacuated.

3 Materials which (in themselves) are capable of detonation or of explosive decomposition or of explosive reaction but which require a strong initiating source or which must be heated under confinement before initiation. Includes materials which are sensitive to thermal or mechanical shock at elevated temperatures and pressures or which react explosively with water without requiring heat or confinement. Fire fighting should be done from an explosion resistant location.

2 Materials which (in themselves) are normally unstable and readily undergo violent chemical change but do not detonate. Includes materials which can undergo chemical change with rapid release of energy at normal temperatures and pressures or which can undergo violent chemical change at elevated temperatures and pressures. Also includes those materials which may react violently with water or which may form potentially explosive mixtures with water. In advanced or massive fires, fire fighting should be done from a safe distance or from a protected location.

1 Materials which (in themselves) are normally stable but which may become unstable at elevated temperatures and pressures or which may react with water with some release of energy but not violently. Caution must be used in approaching the fire and applying water.

0 Materials which (in themselves) are normally stable even under fire exposure conditions and which are not reactive with water. Normal fire fighting procedures may be used.

APPENDIX C

DIESEL EXHAUST COMPONENT DATA SHEETS

Substances are listed in same order as found in Table 2.1

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Ethanal POPULAR (TRIVIAL) NAME: Acetaldehyde

2. SYNONYMS: Acetic Aldehyde Ethal Aldehyde

3. STRUCTURAL FORMULA: CH_3CHO

4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

3.2 ppm	(39)
2-88 $\mu g/m^3$	(43)
35-777 mg/m^3	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	200	(ppm)	360	(mg/m3)	(39/8)
USSR		(ppm)	5	(mg/m3)	(39)
FRG	200	(ppm)	360	(mg/m3)	(39)
DDR		(ppm)	100	(mg/m3)	(39)
Sweden		(ppm)	90	(mg/m3)	(39)
		(ppm)		(mg/m3)	

W. Germany 4.0 $\mu g/m^3$ for 30 min basic standard	(8)
USSR 12.0 $\mu g/m^3$ for 30 min permissible	(8)
ACGIH 100 ppm (180 $\mu g/m^3$) TLV standard	(44)

7. "THRESHOLD LIMIT VALUE" (TLV): 100; 200 (ppm) (37/44; 41)

8. LIMITS OF INFLAMMABILITY IN AIR: lower 4.0% upper 6.0% (3)
   3.97% 57.0% (40)

9. SPECIFIC GRAVITY: @ 18/4°C 0.783

10. COLOR: Colorless liquid or gas THRESHOLD: (ppm)

11. ODOR: Apple-like/pungent THRESHOLD: .21 (ppm) 100% recg.

12. TOXICITY: Moderate Comments/Symptoms: Acute exposure to high vapor levels may result in pulmonary edema and narcosis. (44) Large doses may cause death by respiratory paralysis. (8)

13. IRRITANT LEVEL: High Comments/Symptoms: Eye irritation, 25-50 ppm (15 min); respiratory tract irritation, 134 ppm (30 min); nose/throat iritation, 200 ppm (15 min).

14. AGENT CLASSIFICATION: Possibly mutagenic (44)

15. LONG TERM EFFECTS: Chronic effects have not been documented. (44)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 2-Propanone POPULAR (TRIVIAL) NAME: Acetone
2. SYNONYMS: Dimethyl Keytone β-Keytopropane Pyroacetic Ether
3. STRUCTURAL FORMULA: CH_3COCH_3
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

25-200 $\mu g/m^3$	(43)
459-1164 mg/m^3	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	1000 (ppm)	2400 (mg/m3)	(39/37)
FRG	1000 (ppm)	2400 (mg/m3)	(39)
USSR	(ppm)	200 (mg/m3)	(39)
DDR	(ppm)	1000 (mg/m3)	(39)
Sweden	(ppm)	1200 (mg/m3)	(39)
CSSR	(ppm)	800 (mg/m3)	(39)

NIOSH - 250 ppm; 590 mg/m^3 TWA (44)

7. "THRESHOLD LIMIT VALUE" (TLV): 1000 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 2.55% % upper 12.8% % (40/3)
9. SPECIFIC GRAVITY: @ 20°C 0.791 (39)
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: Sweet/pungent THRESHOLD: Distinct odor 680 (ppm)
140 (ppm) 100% recg.
12. TOXICITY: Moderate-High Comments/Symptoms: Chronic conjunctivitis, bronchitis, gastritis, 25-920 ppm; irritation of mucous membrane, 300 ppm; severe toxic effects, 4000 (ppm) (60 min) symptoms of illness, 800 ppm (60 min)
13. IRRITANT LEVEL: High (37) Comments/Symptoms: Severe eye irritant; (60 min) unsatisfactory > 400 ppm = 965 $\mu g/m^3$ (39)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Ethyne POPULAR (TRIVIAL) NAME: Acetylene
2. SYNONYMS: Ethine
3. STRUCTURAL FORMULA: CH:CH or C_2H_2
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

0.8-7.0 ppm	(43)
14.1% of emitted HC	(39)
.3 - 1.7 ppm	(10)
4 ppm vapor phase	(20)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

Unregulated in USA (9)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 2.5%% upper 100% (3)
   2.5% 81% (5)
9. SPECIFIC GRAVITY: @ 60°F 0.9057 (5)
10. COLOR: Colorless gas THRESHOLD: (ppm)
11. ODOR: Ethereal, garlic-like THRESHOLD: (ppm)
12. TOXICITY: Low Comments/Symptoms: Not significant; rapid respiration, reduced alertness, nausea, unconscious (4)
13. IRRITANT LEVEL: Low Comments/Symptoms: Effects mucous membrane
14. AGENT CLASSIFICATION: Simple asphixiant, anesthetic
15. LONG TERM EFFECTS: None determined

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Propenal POPULAR (TRIVIAL) NAME: Acrolein
2. SYNONYMS: Acraldehyde Acrylic Aldehyde Acrylaldehyde
3. STRUCTURAL FORMULA: $CH_2 = CHCHO$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

10 mg/mi	(20)
4 ppm vapor phase	(20)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)		(mg/m3)		
FRG	(ppm)	20	(mg/m3) if emission > 0.1 kg/hr than MEC		(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA	0.1	(ppm)	0.25	(mg/m3)	(39/8/37)
FRG	0.1	(ppm)	0.25	(mg/m3)	(39)
USSR		(ppm)	0.70	(mg/m3)	(39)
DDR		(ppm)	0.25	(mg/m3)	(39)
Sweden		(ppm)	0.25	(mg/m3)	(39)
CSSR		(ppm)	0.50	(mg/m3)	(39)

7. "THRESHOLD LIMIT VALUE" (TLV): 0.1 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 2.80% % upper 31.0% % (3)
9. SPECIFIC GRAVITY: @ 20/20°C 0.8427
10. COLOR: Colorless, yellow liquid THRESHOLD: (ppm)
11. ODOR: Burnt sweet/pungent THRESHOLD: PIT 100% =.21 (ppm) USSR = 0.8 mg/m^3
12. TOXICITY:

intolerable = 5 ppm (1 min); fatal: 150 ppm (10 min). (39) Acute exposure may cause bronchitis or pulmonary edema (44)

13. IRRITANT LEVEL: High Comments/Symptoms: Severe eye irritant (37), irritates mucous membrane (8)

14. AGENT CLASSIFICATION: Cytotoxin (44) / mutagenic
15. LONG TERM EFFECTS: sensitization, asthma have been reported (8)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Benzenecarbonal POPULAR (TRIVIAL) NAME: Benzaldehyde
2. SYNONYMS: Benzenecarboxaldehyde Artificial Almond Oil
3. STRUCTURAL FORMULA: C_6H_5CHO
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

0.3 ppm	(39)
177-706 mg/m^3	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

Unregulated in US (9)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0% upper % % %
9. SPECIFIC GRAVITY: @ 15/4°C 1.05
10. COLOR: Colorless THRESHOLD: (ppm)
11. ODOR: Bitter almonds THRESHOLD: .006 (ppm) T.O.C.
12. TOXICITY: None Comments/Symptoms: Can cause respiratory problems (37)
13. IRRITANT LEVEL: Low Comments/Symptoms: Narcotic in high concentrations (8); Severe eye irritant (39)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: None determined

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Phene POPULAR (TRIVIAL) NAME: Benzene
2. SYNONYMS: Benzol Cyclohexatriene Phenyl Hydride
3. STRUCTURAL FORMULA: $C_6 H_6$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

2.4% of emitted HC	(39)
2000 $\mu g/m^3$	(43)
0.3-1.0 ppm	(10)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

Hungary	6	(ppm)	20	(mg/m3)	(39)
CSSR	--	(ppm)	50	(mg/m3)	(39)
Sweden	--	(ppm)	30	(mg/m3)	(39)
Switzld.	10	(ppm)	--	(mg/m3)	(39)
UK	50	(ppm)	160	(mg/m3)	(39)
Poland	31	(ppm)	100	(mg/m3)	(39)
Italy	25	(ppm)	80	(mg/m3)	(39)
Yugosl.	25	(ppm)	80	(mg/m3)	(39)
DDR	16	(ppm)	32	(mg/m3)	(39)
USSR	1.5	(ppm)	5	(mg/m3)	(39)
USA (Fed)	10	(ppm)		(mg/m3)	(39)
FRG	10	(ppm)	32	(mg/m3)	(39)
ACGIH	25	(ppm)	80	(mg/m3)	(45)

ACC - 25 ppm; AMP - 50 ppm, 10 min (45)

7. "THRESHOLD LIMIT VALUE" (TLV): 10 (ppm) (39)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.3% upper 7.1% (3)
   1.4% 7.1% (40)
9. SPECIFIC GRAVITY: @ 20/4°C 0.8786
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: Characteristic THRESHOLD: 1.0 (ppm) USSR (39)
12. TOXICITY: High Comments/Symptoms: Acute exposure results in nausea, convulsions, coma or death; hemorrhaging. (44) Severe toxic effects: 1500 ppm (60 min); illness: illness: 500 ppm; unsatisfactory: 50 ppm (39)
13. IRRITANT LEVEL: Moderate Comments/Symptoms: Eye irritant
14. AGENT CLASSIFICATION: Carcinogenic/FRG 1973 (39) Carcinogenic/USA (55); leukemogenic (39/44)
15. LONG TERM EFFECTS: May result in damage to the hematopietic system, possible development of leukemia, anemia, thromboctopenia; may cause chronic blood changes.

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Vinylethylene POPULAR (TRIVIAL) NAME: 1,3-Butadiene
2. SYNONYMS: Erythrene Divinyl Bivinyl
3. STRUCTURAL FORMULA: CH_2:CHCH:CH_2
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

8 $\mu g/m^3$	(43)
2 ppm vapor phase	(20)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)	
FRG	(ppm)	(mg/m3)	
if emission > 73 kg/hr, than MEC - 150 mg/m^3			(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	1000 (ppm)	2200 (mg/m3)	(39/44)
USSR	45 (ppm)	100 (mg/m3)	(39/44)
FRG	1000 (ppm)	2200 (mg/m3)	(39/44)
DDR	(ppm)	500 (mg/m3)	(39/44)
CSSR	(ppm)	500 (mg/m3)	(39/44)
	(ppm)	(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 1000 (ppm) (41/44)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 2.0 % upper 12.0% (3)
   Explosion hazard % %
9. SPECIFIC GRAVITY: @ 60°F 1.9153 (5)
10. COLOR: Colorless gas THRESHOLD: (ppm)
11. ODOR: Undefined/mildly aromatic THRESHOLD: 1.3 (ppm) T.O.C. 100% (39)
12. TOXICITY: Low-high Comments/Symptoms: Rapid respiration, nausea, unconsciousness. As a narcotic, produces drowsiness, headache, vertigo, unconsciousness, respiratory paralysis, death (4/44)
13. IRRITANT LEVEL: Low Comments/Symptoms: Slight irritation of eyes and upper respiratory tract, no other effects: 8000 ppm (8 hrs); irritation of respiratory system: 10,000 ppm (1 min) (39)
14. AGENT CLASSIFICATION: Anesthetic/mild asphyxiant (4)
15. LONG TERM EFFECTS: Chronic exposure may result in central nervous system disorders, diseases of liver, tendencies toward leukemia. These have not been observed in humans. (44)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: n-Butane POPULAR (TRIVIAL) NAME: n-Butane
2. SYNONYMS: Methylethylmethane
3. STRUCTURAL FORMULA: $CH_3CH_2CH_2CH_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   5.3% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)	
FRG	(ppm)	(mg/m3)	

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	500 (ppm)	1200 (mg/m3)	(39)
FRG	1000 (ppm)	2400 (mg/m3)	(39)
USSR	(ppm)	300 (mg/m3)	(39)
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 500 (ppm) (39)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.9% % upper 8.5% % (40)
9. SPECIFIC GRAVITY: 0.60 liquified
10. COLOR: Colorless gas THRESHOLD: (ppm)
11. ODOR: Undefined THRESHOLD: not detectable <5000 ppm; 4960 (ppm) T.O.C.
12. TOXICITY: None Comments/Symptoms:
13. IRRITANT LEVEL: None Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: Drowsiness, no other effects: 10,000 ppm (10 min)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 1-Butene POPULAR (TRIVIAL) NAME: α-Butylene
2. SYNONYMS: Ethylethylene
3. STRUCTURAL FORMULA: CH_3CH_2:$CHCH_2$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   1.8% of emitted HC (39)

   2 ppm vapor phase (20)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 16.% % upper 10.0% % (40)
9. SPECIFIC GRAVITY: 0.67 liquified
10. COLOR: Gas THRESHOLD: (ppm)
11. ODOR: Gashouse THRESHOLD: faint odor 59 mg/m^3 / 69 (ppb) T.O.C.
12. TOXICITY: Comments/Symptoms:
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: (trans) 2-Butene POPULAR (TRIVIAL) NAME: β-Butylene
2. SYNONYMS: Dimethylethylene
3. STRUCTURAL FORMULA: $CH_3CH:CHCH_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.6% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): suggested 4000 (ppm) (39)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.8% % upper 9.7% % (40)
9. SPECIFIC GRAVITY: .64 liquified
10. COLOR: Gas THRESHOLD: (ppm)
11. ODOR: Undefined THRESHOLD: 0.6 (ppm) T.O.C.
12. TOXICITY: Comments/Symptoms:
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 1-Butanal POPULAR (TRIVIAL) NAME: Butyraldehyde
2. SYNONYMS: Butyaldehyde Butyric Aldehyde
3. STRUCTURAL FORMULA: $CH_3CH_2CH_2CHO$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.3 ppm (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA		(ppm)		(mg/m3)	
FRG		(ppm)		(mg/m3)	

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USSR	1.5	(ppm)	5	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

   P.O.L. 200 ppm (39)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 2.5% % upper 12.5% % (40)
9. SPECIFIC GRAVITY: @ 20/4°C 0.817
10. COLOR: THRESHOLD: (ppm)
11. ODOR: Sweet/rancid THRESHOLD: .039 (ppm)
12. TOXICITY: Low Comments/Symptoms: Rat inhalation - 60,000 ppm (.5 hr)
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: n-Hexanal POPULAR (TRIVIAL) NAME: Caproaldehyde
2. SYNONYMS: Hexaldehyde n-Caproic Aldehyde n-Hexoic
3. STRUCTURAL FORMULA: $CH_3(CH_2)_4CHO$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.2 ppm (39)

   0-1589 mg/m^3 (10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0% upper % (3)
   % %
9. SPECIFIC GRAVITY: @ 20/4°C 0.833
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: Pungent THRESHOLD: (ppm)
12. TOXICITY: None Comments/Symptoms: Can cause respiratory problems (37)
13. IRRITANT LEVEL: Moderate Comments/Symptoms: Severe eye irritant (37)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Carbon Dioxide POPULAR (TRIVIAL) NAME: Carbon Dioxide
2. SYNONYMS: Carbon Anhydride
3. STRUCTURAL FORMULA: CO_2
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

17%	(43)
1.5-12%	(49)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	5000 (ppm)	9000 (mg/m3)	(41)
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 5000 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0% % upper % %
9. SPECIFIC GRAVITY: @ 60°C 1.977; @ 0°C 1.521 (5)
10. COLOR: Colorless THRESHOLD: (ppm)
11. ODOR: Odorless THRESHOLD: (ppm)
12. TOXICITY: High Comments/Symptoms: Increased breathing - 10% (100,000 ppm) in air (few min.); unconsciousness - 12-15 in air%; fatal-25% in air.
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION: Simple asphyxiant
15. LONG TERM EFFECTS: Continuous exposure to 1.5% CO_2 may cause changes in some physiological processes (44)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Carbon Monoxide POPULAR (TRIVIAL) NAME: Carbon Monoxide
2. SYNONYMS: None
3. STRUCTURAL FORMULA: CO
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

12.2 ppm	(43)
1 g/m	(20)
76-7842 mg/m^3	(10)
200-2000 ppm	(49)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	50 (ppm)	55	(mg/m3)		(39)
	(ppm)		(mg/m3)		
	(ppm)		(mg/m3)		
	(ppm)		(mg/m3)		
	(ppm)		(mg/m3)		

Standard recommended by NIOSH is 35 pm with a ceiling of 200 ppm (44)
ACGIH - 100 ppm (110 mg/m^3) (45)

7. "THRESHOLD LIMIT VALUE" (TLV): 50 (ppm) (4/41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 12.5% % upper 74.20% % (3/40)
9. SPECIFIC GRAVITY: @ 60% F 1.250 (39); @ 70%F .9678 (5)
10. COLOR: Colorless gas THRESHOLD: (ppm)
11. ODOR: Odorless THRESHOLD: (ppm)
12. TOXICITY: High Comments/Symptoms: Slight to moderate discomfort, 2-3 hrs (200-400 ppm); severe discomfort, nausea, 2 hrs (1000-2000 ppm); unconsciousness, 30 min (2000-2500 ppm); fatal, > 1 hr. (4000 ppm)
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION: Chemical asphyxiant
15. LONG TERM EFFECTS: Not readily substantiated (4)

    Severe carbon monoxide poisioning has been reported to permanently damage the extra-pyramidal system (44)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: (trans) 2-Butenal   POPULAR (TRIVIAL) NAME: Crotonaldehyde
2. SYNONYMS: β-Methylacrolein   Crotonic Aldehyde   Propylene Aldehyde
3. STRUCTURAL FORMULA: $CH_3CH: CHCHO$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   1-18 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	2	(ppm)	6	(mg/m3)	(8/37/39)
FRG	2	(ppm)	6	(mg/m3)	(39)
USSR	0.2	(ppm)	0.5	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 2 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 2.12% % upper 15.5% % (3/40)
9. SPECIFIC GRAVITY: @ 60°F 0.85
10. COLOR: THRESHOLD: (ppm)
11. ODOR: Pungent   THRESHOLD: 0.2 (ppm) T.O.C.
12. TOXICITY: Comments/Symptoms: Lethal concentration for guinea pigs - 2000 ppm (8)
13. IRRITANT LEVEL: High   Comments/Symptoms: Highly irritating to eyes, skin, mucous membrane (8)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: Can cause respiratory problems (37)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Azimethylene POPULAR (TRIVIAL) NAME: Diazomethane
2. SYNONYMS:
3. STRUCTURAL FORMULA: CH_2NN
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   30 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	0.2	(ppm)	0.4	(mg/m3)	(39)
FRG	0.2	(ppm)	0.4	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 0.2 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower % upper %

   -23°C may explode % %
9. SPECIFIC GRAVITY:
10. COLOR: Yellow THRESHOLD: (ppm)
11. ODOR: Musty THRESHOLD: (ppm)
12. TOXICITY: Comments/Symptoms: Carcinogenic
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION: Carcinogenic
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 2,3-Dimethylbutane   POPULAR (TRIVIAL) NAME: 2,3-Dimethylbutane
2. SYNONYMS: Isopropyldimethylmethane   Bi-isopropyl   Diisopropyl
3. STRUCTURAL FORMULA: $(CH_3)_2CHCH(CH_3)_2$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.5% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.2% % upper 7.0% % (40)
9. SPECIFIC GRAVITY: @ 17/4°C 0.67
10. COLOR: THRESHOLD: (ppm)
11. ODOR: THRESHOLD: (ppm)
12. TOXICITY: Comments/Symptoms:
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 2,3-Dimethylpentane   POPULAR (TRIVIAL) NAME: 2,3-Dimethylpentane
2. SYNONYMS: Ethylisopropylmethylmethane
3. STRUCTURAL FORMULA: $CH_3CH(CH_3)CH(CH_3)CH_2CH_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.9% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.1% % upper 6.7% %
9. SPECIFIC GRAVITY: @ 20°C 0.695
10. COLOR: Colorless liquid   THRESHOLD: (ppm)
11. ODOR: None   THRESHOLD: (ppm)
12. TOXICITY: Comments/Symptoms:
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 2,4-Dimethylpentane POPULAR (TRIVIAL) NAME: 2,4-Dimethylpentane
2. SYNONYMS: Di-isopropylmethane
3. STRUCTURAL FORMULA: $(CH_3)_2CHCH_2CH(CH_3)_2$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.3% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

   USA (ppm) (mg/m3)

   FRG (ppm) (mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

   (ppm) (mg/m3)

   (ppm) (mg/m3)

   (ppm) (mg/m3)

   (ppm) (mg/m3)

   (ppm) (mg/m3)

   (ppm) (mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0% upper % (40)
   % %
9. SPECIFIC GRAVITY: @ 20°C 0.67
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: None THRESHOLD: (ppm)
12. TOXICITY: Comments/Symptoms:
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Ethane   POPULAR (TRIVIAL) NAME: Ethane

2. SYNONYMS: Bimethyl Methylmethane Dimethyl Ethyl Hydride

3. STRUCTURAL FORMULA: CH_3CH_3 or C_2H_6

4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

1.8% of emitted HC	(39)
0.5 - 1.3 ppm	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USSR	(ppm)	300 (mg/m3)	(39)
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	

Unregulated in USA (9)

7. "THRESHOLD LIMIT VALUE" (TLV): Suggested 6200 (ppm) (39)

8. LIMITS OF INFLAMMABILITY IN AIR: lower 3.0% % upper 12.5% % (40/3)

9. SPECIFIC GRAVITY: @ 60°F 1.047 (5); @ -100°C 0.561 (39)

10. COLOR: Colorless gas   THRESHOLD: (ppm)

11. ODOR: Undefined   THRESHOLD: 1520 (ppm) T.O.C.

12. TOXICITY: Low   Comments/Symptoms: Not significant; rapid respiation, reduced alertness, nausea, unconscious (4)

13. IRRITANT LEVEL: Low   Comments/Symptoms: Effects mucous membrane

14. AGENT CLASSIFICATION: Asphyxiant

15. LONG TERM EFFECTS: No effect level: < 50,000 ppm (39)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Ethylbenzene POPULAR (TRIVIAL) NAME: Ethylbenzene
2. SYNONYMS: Phenylethane Ethylbenzol
3. STRUCTURAL FORMULA: $C_6H_5C_2H_5$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.7% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA		(ppm)		(mg/m3)	
FRG		(ppm)	150	(mg/m3) if > 3 kg/hr	(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	100	(ppm)	435	(mg/m3)	(39/41)
FRG	100	(ppm)	435	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 100 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.0% % upper 6.7% % (40)
9. SPECIFIC GRAVITY: @ 20/4°C 0.867
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: None THRESHOLD: (ppm)
12. TOXICITY: None Comments/Symptoms:
13. IRRITANT LEVEL: Low Comments/Symptoms: Eye irritant
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Ethene POPULAR (TRIVIAL) NAME: Ethylene
2. SYNONYMS: Etherin Elayl Olefiant Gas
3. STRUCTURAL FORMULA: $H_2C{:}CH_2$ or C_2H_4
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

14.5% of emitted HC	(39)
43 mg/mi	(20)
20 ppm in vapor phase	(20)
9-26.1 ppm	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

Unregulated in USA (9)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR:

	lower		upper	
	2.7%		36.0%	(3)
	2.75%		28.6%	(40)
	3.1%		32.0%	(5)

9. SPECIFIC GRAVITY: @ 15°C .9740 (5); @ -102/4°C 0.566 (39)
10. COLOR: Colorless gas THRESHOLD: (ppm)
11. ODOR: Olefinic - sweet unpleasant-neutral THRESHOLD: 700 (ppm) @100% recog.; 400 (ppm) @50% recog.
12. TOXICITY: Low Comments/Symptoms: Not significant; rapid respiration, reduced alertness, nausea, unconscious (4)
13. IRRITANT LEVEL: Low Comments/Symptoms: Effects mucous membrane (4)
14. AGENT CLASSIFICATION: Simple asphxiant/anesthetic in concentrations of 75-90% (5)
15. LONG TERM EFFECTS: None

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 1-Ethyl-4-Methylbenzene POPULAR (TRIVIAL) NAME: p-Ethyltoluene
2. SYNONYMS:
3. STRUCTURAL FORMULA: $CH_3C_6H_4C_2H_5$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.7% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USSR	10	(ppm)	50	(mg/m3)
		(ppm)		(mg/m3)
		(ppm)		(mg/m3)
		(ppm)		(mg/m3)
		(ppm)		(mg/m3)
		(ppm)		(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0% upper % (40)
   % %
9. SPECIFIC GRAVITY: 0.862
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: THRESHOLD: (ppm)
12. TOXICITY: Comments/Symptoms:

13. IRRITANT LEVEL: Comments/Symptoms:

14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Methanal POPULAR (TRIVIAL) NAME: Formaldehyde
2. SYNONYMS: Formalin Oxomethane Methylene Oxide Formic Aldehyde
3. STRUCTURAL FORMULA: HCHO
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

18.3 ppm	(39)
20 mg/mi	(20)
12 ppm vapor phase	(20)
2118-3071 mg/m^3	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

FRG (ppm) MEC = 20 (mg/m3) if emission > 0.1 kg/hr (39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)*	3	(ppm)	3.6	(mg/m3)	(39/44)
*USA	5	(ppm)	6.0	(mg/m3)	(5)
FRG	1	(ppm)	1.2	(mg/m3)	(39/44)
USSR	0.4	(ppm)	0.5	(mg/m3)	(39/44)
Switzld	1	(ppm)	1.2	(mg/m3)	(39/44)
DDR		(ppm)	2	(mg/m3)	(39/44)
Sweden		(ppm)	3	(mg/m3)	(39/44)
CSSR		(ppm)	2	(mg/m3)	(39/44)

ACGIH - TLV of 2 ppm (3 mg/m3) (44)
NIOSH - TLV of 1 ppm (1.2 mg/m3) (44)
ACC = 5 ppm; AMP = 10 ppm; 30 min
Basic/Permissible: W. Germany 36 (mg/m3) 30 min/84 (mg/m3) 30 min (8)
Basic/Permissible: USR 14.4 (mg/m3) 24 hrs/42 (mg/m3) 20 min (8)
Basic/Permissible: Czechoslovakia 18 (mg/m3) 24 hrs/60 (mg/m3) 30 min (8)

7. "THRESHOLD LIMIT VALUE" (TLV): 2; 3 (ppm) (37;39)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 7.0% upper 73.0% (3)
9. SPECIFIC GRAVITY: @ -20/4^{o}C 0.815
10. COLOR: Colorless gas THRESHOLD:
11. ODOR: Hay/pungent THRESHOLD: 1.0 (ppm) 100% PIT/USSR-.07 mg/m^3
12. TOXICITY: High Comments/Symptoms: 100 ppm (1 minute) severe toxic effects; 30 ppm - illness; 10 ppm - unsatisfactory. Symptoms: breathing difficulty; pulmonary edema
13. IRRITANT LEVEL: High Comments/Symptoms: Effects mucous membrane (8); severe eye irritant (37); inhibits lung clearance (28)
14. AGENT CLASSIFICATION: Carcinogenic (28)(20)(55); mutagenic (44)
15. LONG TERM EFFECTS: High incidence of nasal carcinomas (28)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: n-Heptane POPULAR (TRIVIAL) NAME: n-Heptane
2. SYNONYMS: None
3. STRUCTURAL FORMULA: $CH_3(CH_2)_5CH_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   5 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)		(mg/m3)		
FRG	(ppm)	300	(mg/m3) if > 6kg/hr	(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	500	(ppm)	2000	(mg/m3)	(39)
FRG	500	(ppm)	2000	(mg/m3)	(39)
USSR	300	(ppm)	--	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

AGGHI 400 ppm = 1600 mg/m^3 TLV (44)

7. "THRESHOLD LIMIT VALUE" (TLV): 500 (ppm) (39/41/44)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.05% upper 6.7% (3)
   highly flammable 1.1% 6.7% (40)
9. SPECIFIC GRAVITY: @ 20°C 0.68
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: Undefined THRESHOLD: Distinct odor 320 (ppm)
    223 (ppm) T.O.C.
12. TOXICITY: Comments/Symptoms:
13. IRRITANT LEVEL: Moderate Comments/Symptoms: Slight vertigo 1000 ppm (6 min.); 2000 ppm (4 min.). High concentrations: slight nausea, vertigo, intoxication by hilarity; persistent gas taste in mouth. (44)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: May cause low order sensitization of the myocardium to epinephrine. (44)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: n-Hexane POPULAR (TRIVIAL) NAME: Hexane

2. SYNONYMS: Hexyl Hydride Dipropyl (some sources say there are no synyonyms)

3. STRUCTURAL FORMULA: $CH_3(CH_2)_4CH_3$

4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

1.2% of emitted HC	(39)
643 $\mu g/m^3$	(43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA		(ppm)		(mg/m3)	
FRG		(ppm)	300	(mg/m3) if > 6 kg/hr	(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	500	(ppm)	1800	(mg/m3)	(39)
USSR		(ppm)	300	(mg/m3)	(39)
FRG	100	(ppm)	360	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

ACGIH 100 ppm = 360 mg/m^3 TLV (44)

7. "THRESHOLD LIMIT VALUE" (TLV): 500 (ppm) (41/39)

8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.1% upper 7.5% (3)
Highly flammable 1.18% 7.4% (40)

9. SPECIFIC GRAVITY: @ 20/4°C 0.6603

10. COLOR: Colorless liquid THRESHOLD: (ppm)

11. ODOR: Odorless THRESHOLD: (ppm)

12. TOXICITY: Comments/Symptoms:

13. IRRITANT LEVEL: Low Comments/Symptoms: No effect level 2000 ppm (10 min); dizziness 5000 ppm. Asphyxia - high concentrations. Acute exposure: nausea, dizziness, headache. (39/44)

14. AGENT CLASSIFICATION: Asphyxiant

15. LONG TERM EFFECTS: Peripheral neurophathy has been reported resulting from exposure to n-hexane (44)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 2-Methylpropanal POPULAR (TRIVIAL) NAME: Isobutanal
2. SYNONYMS: Isobutyraldehyde Isobutylaldehyde
3. STRUCTURAL FORMULA: $(CH_3)CHCHO$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   $318\text{-}1659$ mg/m^3 (10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.6% % upper 10.6% % (3)
9. SPECIFIC GRAVITY: @ 60°F 0.7938 (39)
10. COLOR: THRESHOLD: (ppm)
11. ODOR: Sweet, pleasant - unpleasant THRESHOLD: 0.236 (ppm) T.O.C.
12. TOXICITY: Low Comments/Symptoms: Lethal concentration for rats in air - 16,000 ppm
13. IRRITANT LEVEL: Moderate-High Comments/Symptoms: Eye irritant (37)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: Can cause respiratory problems (37)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 2-Methylpropane POPULAR (TRIVIAL) NAME: Isobutane
2. SYNONYMS: Trimethylmethane
3. STRUCTURAL FORMULA: $(CH_3)_3CH$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.8% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.8% % upper 8.4% % (40)
9. SPECIFIC GRAVITY: .60 liquified
10. COLOR: Colorless Gas THRESHOLD: (ppm)
11. ODOR: Undefined THRESHOLD: 1.2 (ppm)
12. TOXICITY: Comments/Symptoms:
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 2,2,4-Trimethylpentane POPULAR (TRIVIAL) NAME: Isooctane
2. SYNONYMS: Isobutyltrimethylmethane
3. STRUCTURAL FORMULA: $CCH_2CH(CH_3)_2$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   1.0% of emitted HC (39)
5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.1% % upper 6.0% % (40)
9. SPECIFIC GRAVITY: @ 20/4°C 0.6918
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: THRESHOLD: (ppm)
12. TOXICITY: None Comments/Symptoms:
13. IRRITANT LEVEL: Low Comments/Symptoms: Slight eye irritant
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 2-Methylbutane POPULAR (TRIVIAL) NAME: Isopentane
2. SYNONYMS: Ethyl Dimethyl Methane
3. STRUCTURAL FORMULA: $(CH_3)_2CHCH_2CH_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   3.7% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.4% % upper 7.6% % (40)
9. SPECIFIC GRAVITY: @ 19°C 0.62
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: THRESHOLD: (ppm)
12. TOXICITY: Comments/Symptoms:
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 1,3,5-Trimethylbenzene POPULAR (TRIVIAL) NAME: Mesitylene
2. SYNONYMS:
3. STRUCTURAL FORMULA: $C_6H_3(CH_3)_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.4% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	25	(ppm)	120	(mg/m3)	(41)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 25 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0% upper % (40)
   % %
9. SPECIFIC GRAVITY: @ 20°C 0.865
10. COLOR: THRESHOLD: (ppm)
11. ODOR: Undefined THRESHOLD: (ppm)
12. TOXICITY: None Comments/Symptoms:
13. IRRITANT LEVEL: Low Comments/Symptoms: Slight eye irritant
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Methane POPULAR (TRIVIAL) NAME: Marsh Gas
2. SYNONYMS: Methylhydride
3. STRUCTURAL FORMULA: CH_4
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

16.7% of emitted HC	(39)
13 mg/mi	(20)
2 ppm vapor phase	(20)
.05-7.7 ppm	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USSR	(ppm)	300	(mg/m3)	(39)
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	

Unregulated in USA (9)

7. "THRESHOLD LIMIT VALUE" (TLV): sug. 10,000 (ppm) (39)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 5.0% upper 15.0% (40)
   5.3% 14.0% (3)
9. SPECIFIC GRAVITY: @ 60°F 0.5549 (5); @ -164°C 0.42 (39)
10. COLOR: Colorless gas THRESHOLD: (ppm)
11. ODOR: Odorless THRESHOLD: (ppm)
12. TOXICITY: Low Comments/Symptoms: Not significant; rapid respiration, reduced alertness, nausea, unconsciousness (4)
13. IRRITANT LEVEL: Low Comments/Symptoms: Tolerable @ 1000 ppm (39)
    Can effect mucous membrane and create slight pressure on head and eyes (5)
14. AGENT CLASSIFICATION: Asphyxiant with high concentrations
15. LONG TERM EFFECTS: None determined

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Propyne — POPULAR (TRIVIAL) NAME: Methylacetylene
2. SYNONYMS: Allylene — Propine
3. STRUCTURAL FORMULA: $CH_3C{:}CH$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.9% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)	
FRG	(ppm)	(mg/m3)	

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	1000 (ppm)	1650 (mg/m3)	(39/41)
FRG	1000 (ppm)	1650 (mg/m3)	(39)
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 1000 (ppm) (39/41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.7% % upper --% % (40)
9. SPECIFIC GRAVITY: @ -27/4°C 0.678
10. COLOR: — THRESHOLD: (ppm)
11. ODOR: — THRESHOLD: (ppm)
12. TOXICITY: — Comments/Symptoms:
13. IRRITANT LEVEL: — Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Hexone — POPULAR (TRIVIAL) NAME: Methyl Isobutyl Ketone
2. SYNONYMS: Hexanone — 4-Methyl-2-Pentatone — MIBK
3. STRUCTURAL FORMULA: $CH_3COCH_2CHC(CH_3)_2$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   402 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA		(ppm)		(mg/m3)	
FRG		(ppm)	300	(mg/m3) if > 6kg/hr	(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	100	(ppm)	410	(mg/m3)	(39)
FRG	100	(ppm)	410	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 100 (ppm) (39)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.35% % upper 7.60% % (40/3)
9. SPECIFIC GRAVITY: @ 20/4°C 0.8017
10. COLOR: Colorless liquid — THRESHOLD: (ppm)
11. ODOR: Sweet/sharp — THRESHOLD: Recognition .28 (ppm) 8.0 (ppm)
12. TOXICITY: None — Comments/Symptoms:
13. IRRITANT LEVEL: Moderate — Comments/Symptoms: Complaints >100; eye irritation, 200 ppm; nasal irritation, 400 ppm (39)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET

(References in Brackets)

1. IUC NAME: 2-Methylpentane — POPULAR (TRIVIAL) NAME: 2-Methylpentane
2. SYNONYMS: Dimethylpropylmethane
3. STRUCTURAL FORMULA: $(CH_3)_2CH(CH_2)_2CH_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   1.5% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): (ppm)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.2% % upper 7.0% % (40)
9. SPECIFIC GRAVITY: 0.654
10. COLOR: Colorless liquid — THRESHOLD: (ppm)
11. ODOR: — THRESHOLD: (ppm)
12. TOXICITY: — Comments/Symptoms:
13. IRRITANT LEVEL: — Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Nitric Oxide POPULAR (TRIVIAL) NAME: Nitric Oxide
2. SYNONYMS: Mononitrogen monoxide
3. STRUCTURAL FORMULA: NO
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

3.8 ppm	(43)
20-1500 ppm (NO_x)	(49)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	25	(ppm)	30	(mg/m3)	(41/44)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 25 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0 % upper %
   % %
9. SPECIFIC GRAVITY: @ 60°F 1.3402
10. COLOR: Colorless gas THRESHOLD: (ppm)
11. ODOR: THRESHOLD: (ppm)
12. TOXICITY: High Comments/Symptoms: Burning in chest, 60-150 ppm; dangerous, 100-150 ppm; fatal, 200-700 ppm.
13. IRRITANT LEVEL: High Comments/Symptoms: Irritation of mucous membrane, nose throat irritation (60-150 ppm). Postulated nonirritation--however, no exposure generally includes other nitrogen oxides. (44)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: Methemoglobinemia, pulmonary edema, chronic respiratory problems, dyspepsia, loss of strength

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Nitroethane POPULAR (TRIVIAL) NAME: Nitroethane
2. SYNONYMS: None
3. STRUCTURAL FORMULA: $CH_3CH_2NO_2$ or $C_2H_5NO_2$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   3-6 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	100	(ppm)	310	(mg/m3)	(39/41)
FRG	100	(ppm)	310	(mg/m3)	(39)
USSR	10	(ppm)	30	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 100 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 3.4% upper % (3)
   % %
9. SPECIFIC GRAVITY: @ 20/20°C 1.05
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: None THRESHOLD: (ppm)
12. TOXICITY: Comments/Symptoms: Lethal - rabbit 1/2: 1000 ppm (6 hrs)
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Nitromethane POPULAR (TRIVIAL) NAME: Nitromethane
2. SYNONYMS: None
3. STRUCTURAL FORMULA: CH_3NO_2
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   20 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	100 (ppm)	250	(mg/m3)	(39)
FRG	100 (ppm)	250	(mg/m3)	(39)
USSR	12 (ppm)	30	(mg/m3)	(39)
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 100 (ppm) (39)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 7.3% upper % (3)

   % %
9. SPECIFIC GRAVITY: @ 20/4°C 1.13
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: Undetermined THRESHOLD: < 100 (ppm)
12. TOXICITY: High Comments/Symptoms: Unsatisfactory: 200 ppm; illness: 500 ppm; severe toxic effects: 800 ppm (60 min.)
13. IRRITANT LEVEL: Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Nitrogen Dioxide POPULAR (TRIVIAL) NAME: Nitrogen Dioxide
2. SYNONYMS: None
3. STRUCTURAL FORMULA: NO_2
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   2.9 ppm (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	5 (ppm)	9 (mg/m^3)	(41/44)
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	

   NIOSH ceiling of 1 ppm (44)

7. "THRESHOLD LIMIT VALUE" (TLV): 5 (ppm) (44)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0 % upper %
   % %
9. SPECIFIC GRAVITY: @ 70°F 1.58
10. COLOR: Redish-brown gas THRESHOLD: (ppm)
11. ODOR: Characteristic THRESHOLD: (ppm)
12. TOXICITY: High Comments/Symptoms: Immediate irritation to eyes, nose, throat, headache 60-150 ppm; dangerous, 100-150 ppm (30-60 min); fatal, 200-700 ppm (short exposure). Acute exposure: headache, nausea, collapse.
13. IRRITANT LEVEL: High Comments/Symptoms: Lower concentration: bronchial irritation
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: May result in severe pulmonary irritation/acute pulmonary (44) edema, possible emphysema, toxic methemoglobinema, dyspepsia, gradual loss of strength (39)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: n-Octane POPULAR (TRIVIAL) NAME: n-Octane

2. SYNONYMS: None

3. STRUCTURAL FORMULA: $CH_3(CH_2)_6CH_3$

4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

5-800 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)	
FRG	(ppm)	(mg/m3)	

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	500	(ppm)	2350	(mg/m3)	(39)
FRG	500	(ppm)	2350	(mg/m3)	(39)
USSR		(ppm)	300	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 500; 400 (ppm) (39; 41)

8. LIMITS OF INFLAMMABILITY IN AIR: lower .95% upper % (3/41)
% %

9. SPECIFIC GRAVITY: @ 25/4°C 0.70

10. COLOR: THRESHOLD: (ppm)

11. ODOR: Undefined THRESHOLD: Distinct Odor 250 (ppm)
150 (ppm) O.T.V. (39)

12. TOXICITY: Comments/Symptoms:

13. IRRITANT LEVEL: Comments/Symptoms:

14. AGENT CLASSIFICATION:

15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: n-Pentane POPULAR (TRIVIAL) NAME: n-Pentane

2. SYNONYMS: None

3. STRUCTURAL FORMULA: $CH_3(CH_2)_3CH_3$

4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

2.5% of emitted HC	(39)
256 $\mu g/m^3$	(43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA		(ppm)		(mg/m3)	
FRG		(ppm)	300	(mg/m3) if > 6 kg/hr	(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	1000	(ppm)	2950	(mg/m3)	(39)
FRG	1000	(ppm)	2950	(mg/m3)	(39)
USSR		(ppm)	300	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 1000 (ppm) (39)

8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.5% upper 7.8% (3)
1.4% 7.8% (40)

9. SPECIFIC GRAVITY: @ 20/4°C 0.626

10. COLOR: Colorless liquid THRESHOLD: (ppm)

11. ODOR: Undefined THRESHOLD: 990 (ppm) T.O.C.

12. TOXICITY: Comments/Symptoms:

13. IRRITANT LEVEL: Comments/Symptoms:

14. AGENT CLASSIFICATION:

15. LONG TERM EFFECTS: No effect level: 5000 ppm (10 min)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Methyl-n-Propyl Ketone POPULAR (TRIVIAL) NAME: 2-Pentanone
2. SYNONYMS: Ethylaceton
3. STRUCTURAL FORMULA: $CH_3COC_3H_7$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   84 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	200	(ppm)	700	(mg/m3)	(39)
FRG	200	(ppm)	700	(mg/m3)	(39)
USSR	56	(ppm)	200	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 200 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.5 % upper 8.2 % (4)
   % %
9. SPECIFIC GRAVITY: @ 15/15°C 0.812
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: Undefined THRESHOLD: Distinct odor 13 (ppm)
    8 (ppm) T.O.V.
12. TOXICITY: None Comments/Symptoms:
13. IRRITANT LEVEL: None Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: None

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Propene POPULAR (TRIVIAL) NAME: Propylene
2. SYNONYMS: Methylethylene Methylethene
3. STRUCTURAL FORMULA: $CH_3CH{:}CH_2$ or C_3H_6
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

14 mg/mi	(20)
4 ppm in diesel vapor	(20)
0.5 - 15.1 ppm	(10)
6.3% of emitted HC	(39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)
(ppm)	(mg/m3)

7. "THRESHOLD LIMIT VALUE" (TLV): Suggested 4000 (ppm) (39)
   1000 (ppm) (4)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 2.0% upper 11.1% (40)
   2.4% 10.3% (3)
9. SPECIFIC GRAVITY: @ -47/4°C 0.609 (39); @ 60°F 1.476 (5)
10. COLOR: Colorless gas THRESHOLD: (ppm)
11. ODOR: Aromatic neutral to unpleasant THRESHOLD: 67.6 (ppm) T.O.C.
12. TOXICITY: Low Comments/Symptoms: Not significant. May cause rapid respiration, reduced alertness, nausea, unconsciousness
13. IRRITANT LEVEL: Low Comments/Symptoms: May effect mucous membrane/ eye irritation
14. AGENT CLASSIFICATION: Mild asphyxiant
15. LONG TERM EFFECTS: None determined

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Sulfer Dioxide   POPULAR (TRIVIAL) NAME: Sulfer Dioxide
2. SYNONYMS: Sulfurous Anhydride   Sulferous Oxide
3. STRUCTURAL FORMULA: SO_2
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

1 ppm	(43)
7.26-222.3 g/hr	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	5 (ppm)	13 (mg/m3)	(41/44)
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	
	(ppm)	(mg/m3)	

**NIOSH - 2 ppm TWA - believe federal standard can cause adverse respiratory effects by increasing airway resistance. (44) ACGIH - 2 ppm TWA (44)

7. "THRESHOLD LIMIT VALUE" (TLV): 5 (ppm) (41/44)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0% upper % % %
9. SPECIFIC GRAVITY: @ 0°C 2.264 (5)
10. COLOR: Colorless gas   THRESHOLD: (ppm)
11. ODOR: Suffocating   THRESHOLD: 3-5 (ppm) (37)
12. TOXICITY: None   Comments/Symptoms: Fatal from asphyxia
13. IRRITANT LEVEL: High   Comments/Symptoms: Noticeable, 3-5 pm; throat irritation/constriction of chest, 8-12 ppm; extreme irritation, 150 ppm; sense of suffocation, 500 ppm
14. AGENT CLASSIFICATION: Asphyxiant - possible co-carcinogenic agent
15. LONG TERM EFFECTS: Over exposure may result in chemical bronchopneumonia with bronchiolitis obliterans. Chronic exposure may result in dyspnea, increased mucous excretion.

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Phenylmethane POPULAR (TRIVIAL) NAME: Toluene
2. SYNONYMS: Methylbenzene Toluol Methacide
3. STRUCTURAL FORMULA: $C_6H_5CH_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

3.1% of emitted HC	(39)
4100 $\mu g/m^3$	(43)
0.1-1.0 ppm	(10)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA		(ppm)		(mg/m3)	
FRG		(ppm)	150	(mg/m3) if emission > 3 kg/hr	(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	200	(ppm)	750	(mg/m3)	(39)
CSSR		(ppm)	200	(mg/m3)	(39)
USSR	13	(ppm)	50	(mg/m3)	(39)
FRG	200	(ppm)	750	(mg/m3)	(39)
DDR		(ppm)	200	(mg/m3)	(39)
Sweden		(ppm)	375	(mg/m3)	(39)

ACGIH - 100 ppm (TWA) 375 mg/m3 (44)

NIOSH - 100 ppm (TWA), ceiling of 200 ppm for 10 min (44)

7. "THRESHOLD LIMIT VALUE" (TLV): 200 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.2% upper 7.1% (3)
   lower 1.27% upper 6.75% (40)
9. SPECIFIC GRAVITY: @ 20/4°C 0.867
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: Sweet/sour pungent THRESHOLD: distinct odor 70 (ppm)
    1.75 (ppm) 100% recog.
12. TOXICITY: High Comments/Symptoms: Unsatisfactory: > 100 ppm; illness: 300 ppm; severe toxicity: 1000 ppm (60 min). Symptoms: headache, dizziness, fatique, collapse, coma (44)
13. IRRITANT LEVEL: High Comments/Symptoms: May cause irritation of eyes, respiratory track, skin (44)
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: Acute exposure results in central nervous system depression. (44)

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 1,2,4-Trimethylbenzene POPULAR (TRIVIAL) NAME: 1,2,4-Trimethylbenzene
2. SYNONYMS: Pseudocumene Asym-trimethylbenzene
3. STRUCTURAL FORMULA: $C_6H_3(CH_3)_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   0.4% of emitted HC (39)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)	
FRG	(ppm)	(mg/m3)	

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed) 25	(ppm)	120	(mg/m3)	(39/41)
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	
	(ppm)		(mg/m3)	

   P.O.L. 100 ppm (39)

7. "THRESHOLD LIMIT VALUE" (TLV): 25 (ppm) (41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 0% upper % (40) % %
9. SPECIFIC GRAVITY: @ 20°C 0.88
10. COLOR: Colorless liquid THRESHOLD: (ppm)
11. ODOR: THRESHOLD: (ppm)
12. TOXICITY: Comments/Symptoms:

13. IRRITANT LEVEL: Low Comments/Symptoms: Slight irritation of eyes/nose-rats @ 1000 ppm, 15 x 6 hrs.

14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS:

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: 1,3-Dimethylbenzene   POPULAR (TRIVIAL) NAME: m-Xylene
2. SYNONYMS: Xylol
3. STRUCTURAL FORMULA: $C_6H_4(CH_3)_2$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   1.9% of emitted HC (m+p-xylene)* (39)

   30-5500 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA	(ppm)	(mg/m3)
FRG	(ppm)	(mg/m3)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	100	(ppm)	435	(mg/m3)	(41/44)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

   NIOSH - 100 ppm TWA; 200 ppm ceiling (10 min) (44)

7. "THRESHOLD LIMIT VALUE" (TLV): 100 (ppm) (41/44)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.1% upper 7.0% (3)
   lower 1.0% upper 6.0% (40)
9. SPECIFIC GRAVITY: @ 20°C 0.864
10. COLOR: Colorless liquid   THRESHOLD: (ppm)
11. ODOR: Undefined   THRESHOLD: 3.7 (ppm) T.O.C.
12. TOXICITY: Low   Comments/Symptoms: High concentration: dizziness unconsciousness, p·.'monary edema, anorexia, abdominal pain. (44)
13. IRRITANT LEVEL: Low   Comments/Symptoms: Eye irritant
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: Acute exposure may cause central nervous system depression and minor reversible effects on kidneys/liver.

GASEOUS EMISSION DATA SHEET
(References in Brackets)

1. IUC NAME: Methylcyclohexane   POPULAR (TRIVIAL) NAME: Methylcyclohexane
2. SYNONYMS: Cyclohexylmethane   Hexahydroxytoluene
3. STRUCTURAL FORMULA: $CH_3C_6H_{11}$ or $CH_2(CH_2)_4CHCH_3$
4. CONCENTRATION IN DIESEL EMISSIONS, OBSERVED RANGE:

   2-100 $\mu g/m^3$ (43)

5. RESTRICTIONS ON CONCENTRATION IN DIESEL EMISSIONS:

USA		(ppm)		(mg/m3)	
FRG		(ppm)	300	(mg/m3) if > 6kg/hr	(39)

6. RESTRICTIONS ON CONCENTRATION IN AIR:

USA (Fed)	500	(ppm)	2000	(mg/m3)	(39)
FRG	500	(ppm)	2000	(mg/m3)	(39)
USSR	12	(ppm)	50	(mg/m3)	(39)
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	
		(ppm)		(mg/m3)	

7. "THRESHOLD LIMIT VALUE" (TLV): 500 (ppm) (39/41)
8. LIMITS OF INFLAMMABILITY IN AIR: lower 1.2% upper 6.7% (3)
   1.15% % (40)
9. SPECIFIC GRAVITY: @ 20/4°C 0.77
10. COLOR: Colorless liquid   THRESHOLD: (ppm)
11. ODOR: None   THRESHOLD: (ppm)
12. TOXICITY: None   Comments/Symptoms:
13. IRRITANT LEVEL: None   Comments/Symptoms:
14. AGENT CLASSIFICATION:
15. LONG TERM EFFECTS: No sign of illness in monkey @ 373 ppm/ 6 hr/day, 5 day/wk, 10W.

APPENDIX D
TEST DESCRIPTION REFERENCES

This Appendix identifies tests which relate to, or which might be considered for use in association with, emissions testing. The arrangements are as follows:

(1) ASTM Standard Tests by number and title, or description. Volume number follows title.

(2) Measurement and standardized tests by reference and title.

(3) Other measurement references.

(4) Notes of general testing interest.

(1) **American Society for Testing Materials (ASTM) Standard Tests**

#	Title/Description/Volume Number
D-611	Laboratory method to predict the burning quality of distallate fuels: used as a relative measure of the aromatic content of the sample. (11)
D-613-62T	Determines cetane value of fuel. The ignition quality of a diesel fuel is usually expressed in cetane values. (11)
D-1391	Emission testing for odor detection by dilution method, test. (26,45)
D-1607	Tests for nitrogen dioxide content in the atmosphere by Griess-Saltzman reaction test. (26)
D-1608-77	Emission testing of gaseous combustion products for total oxides of nitrogen by phenoldisulfonic acid procedure. (26)
D-1739-70	Constitute content, particulate matter content, of the atmosphere by collecting/analyzing dustfall. (26)
D-1946	Constitute content, carbon monoxide, of reformed gas by gas chromatography test. (26)
D-2009	Test of particulate matter for mass, amount, particle size of atmospheric particulates. (26)
D-2011-65	Constitute content, oxident content, of the atmosphere by continuous analysis/automatic recording. (29)
D-2194	Formaldehyde content test. (29)
D-2306	Constitute content, toluene content, of nonaromatic hydrocarbons (present in xylene and its derivitives. (29)
D-2324	Constitute content of aromatic hydrocarbons and benzene using spectrophotometry test. (29)
D-2360	Hydrocarbons: Monocyclic aromatic HCs, nonaromatic HC content by gas chromatography. (29)
D-2380	Methanol content test.
D-2504-67	Constitute content, carbon monoxide of C_3/lighter HC products by gas chromatography (24)
D-2505	Constitute content, ethane, of high-purity ethylene by gas chromatography test (24)

D-2600	Hydrocarbons, light hydrocarbons, aromatic content of saturated light hydrocarbons (trace quantities) by gas chromatography. (24)
D-2712	Hydrocarbons, trace quantities, of propylene concentrates by gas chromatography. (24)
D-2820-72	Hydrocarbons, C-C_5 hydrocarbon content of the atmosphere by gas chromatography. (26)
D-2887-73	Gas chromatograph-simulated distillation procedure for gaseous hydrocarbons.
D-2912-76	Constitute content, oxidant (ozone) content, of the atmosphere by neutral KI (potassium iodide) method. (26)
D-3162-78	Constitute content, carbon monoxide in the atmosphere, continuous measurement by nondispersive infrared spectrometry. (26)
D-3178	Test for determination of carbon/hydrogen weight percentages in diesel particulate.
D-3211	Emission testing, relative density of black smoke by Ringlemann method. (26)
D-3365	Airborne and particulate size distribution, collected in a liquid media using an electric counter. (26)
D-3416-78	Standard test method for total hydrocarbon, methane, and carbon monoxide in the atmosphere by gas chromatographic method. (26)
D-3449	Test for sulfur dioxide in workplace atmosphere by barium perchlorate method. (26)
D-3563-76T	Emission testing, concentration and particle size distribution of particulate collected in the alundum thimble using a liquid media electronic counter. (26)
D-3608-77T	Constitute content, nitrogen oxides (combined) of the atmosphere by Griess-Saltzman reaction test. (26)
D-3614	Emission testing, laboratories engaged in practice for evaluating. (24)
D-3669-78T	Constitute content, carbon monoxide content in the atmosphere, by manual turbidimetric method. (26)
D-3798-79	Analysis of p-xylene by gas chromatography. (29)
D-3824-79	Oxides of nitrogen in the ambient or workplace atmosphere by the chemiluminescent method, continuous measurement of. (26)

(2) **Measurement/Standard Tests**

Ref #	Test	Description
2	SAE J177 (1970)	Measurement of carbon dioxide, carbon monoxide, and oxides of nitrogen in diesel exhaust. (NDIR/Chemiluminescent analyzer)
2	SAE J215 (1972)	Continuous hydrocarbon analysis of diesel emissions. (FID Method)
	SAE J270 ( ), SAE J816b (1973), SAE J1349 (1980)	Engine Test Code, spark ignition and diesel: measures (standard test) horse power and torque ratings of gas and diesel engines.
	DIN 70020, DIN 6270A, DIN 6270B	European Society of Engineers standardized rating tests for gas and diesel engines
	BS.AU 141 a (1971)	British standards test for gas and diesel engines
10	EPA 13-Mode Test	Stationary Engine Test for measuring HC, CO, and NO_X rates in diesel exhaust
10	EPA Gas Chromotograph	Measures non-reactive HCs, using a single flame ionization detector with a multiple column arrangement and duel gas sampling values.
16	FTD	Federal Test Procedures for emissions testing
16	SET	Sulfate Emissions Test
16	FET	Fuel Economy Test
16	BAC	Barium chloranilate method for sulfuric acid mist analysis (sulfate content)
5	Ilosvay Test	Test for slight detections of acetylene (Ethyne) content
37	West-Gaeke Colormetric Method	For detections of sulfur dioxide
21	PHS Kit	Public Health Service kit of standards - odor measurement
17	Anderson Method	Aerodynamic sizing of particulates
10	Federal Smoke Test	Smoke evaluation procedure

10	Turk Kit Method	EPA (PHS) quality intensity (QI) evaluation: diesel odor rating standards
10	DNPH	Dinitrophenylhydrazine Method: analysis by liquid chromatography for aldehyde determination
2	EPA (transient) Smoke Certification Test	Measures smoke
2	BCA Method	Measures sulfate in particulate
8	Bisulfite Method	Measures "aldehydes" and keytones in atmospheric samples from diesel exhaust
8	Colormetric Determination Methods:	
	o Indole	"adlehydes," formaldehyde
	o Schiff Method	"aldehydes," formaldehyde
	o 4-Phenylazo-phenylhydrazine sulfonic acid	"aldehydes," formaldehyde, acrolein
	o 2-Hydrazino-benzothiazole + p-nitrobenzenediazonium fluoborate	"adlehydes," formaldehyde, aerolein
	o 2-Hydrazino-benzothiazole (HBT)	"aldehydes," formaldehyde
	o 3-Methyl-2-benzothiazolene hydrazone (MBTH)	"aldehydes," formaldehyde
	o (J-acid) 6-Amino-1-naphthol-3-sulfonic acid	"aldehydes," formaldehyde
27	Federal Register, Vol. 42, 1977 - Emission Regulations for Diesel Heavy-Duty Engines, Exhaust test procedures:	
	86.316-79	Carbon monoxide and carbon dioxide analyzer specifications (NDIR method)
	86.317-79	Hydrocarbon analyzer specifications (HFID method)
	86.318-79	Oxides of nitrogen analyzer specifications (chemiluminescence method)

(3) Other Measurement References

"Performance Characteristics of Instrumental Methods for Monitoring Sulfur Dioxide," C.E. Rhodes et al., JAPCA, Vol. 19, No. 8, 1969.

"Comparison of Instrumental Methods to Measure Nitrogen Dioxide," R.E. Baumgardner et al., Env. of Science and Technology, Vol. 19, No. 1, 1975.

"Laboratory Tests and Field Evaluation Study on Sulfur Dioxide and Nitrogen Dioxide Monitors," H. Peperstraete, Proc. of the Fourth Annual International Clean Air Congress, Tokyo, 1977.

"Measurement of Carbon Dioxide, Carbon Monoxide, and Oxides of Nitrogen in Diesel Exhaust," Society of Automotive Engineers, J177, June 1970.

"An Optical Detection Method for NO in the Range of 10^{-2} to 10^{3} ppm by the Chemiluminescent Reaction of NO with O_3," F. Stuhl and H. Niki, Ford Motor Company, Scientific Staff Research Report, Detroit, March 1970.

"Determination of Formaldehyde in Gas Mixtures by the Chromotropic Method," A.P. Altshuller, D.L. Miller, and S.F. Sleva, Anal. Chem., 33, April 1961.

"Determination of the Oxides of Nitrogen by the Phenodisulfonic Acid Method," Robert L. Beatty, L.B. Berger, and H.H. Schrenk, Bureau of Mines Report of Investigations 3687, Pittsburg, PA, 1943.

"Determination of Nitrogen and Nitric Oxide by the Saltzman Method," B.E. Saltzman, Selected Methods of Measurement of Air Pollutants, Public Health Service Publication #999-AP-11, U.S. Department of Health, Education, and Welfare, May 1965.

"Air Pollution Source Testing Manual," H. Devorkin, R.L. Chause, and A.P. Fudurich, Air Pollution District, Los Angeles, December 1972.

"Measurement of Air Pollutants - A Guide to the Selection of Methods," World Health Organization, Geneva, 1969.

"The Physical and Chemical Characteristics of Diesel Particulate Emissions - Measurement Techniques and Fundamental Considerations," W.H. Lipkea and J.H. Johnson, paper 780108 presented at SAE Congress and Exposition, Detroit, MI, 27 February-3 March 1978.

"Application of the 3-Methyl-2-Benzothiazolone Hydrazone Method for Atmospheric Analysis of Aliphatic Aldehydes," A.P. Altshuller and L.J. Leng, Annual Chemistry 35 (10): 1541, 1963.

"A New Spectrophotometric Method for the Determination of Acrolein in Combustion Gases and in the Atmosphere," I.R. Cohen and A.P. Altshuller, Annual Chemistry 33 (6): 726, 1961.

"Methodology for Assignment of Hydrocarbon Photochemical Reactivity Index for Emissions from Mobile Sources," F.M. Black, L.E. High, and J.E. Sigsby, EPA, 1975.

"The Measurement and Analysis of the Physical Character of Diesel Particulate Emissions," C.T. Vuk, A. Jones, and J.H. Johnson, SAE paper 760131, February 1976.

(4) Notes of General Interest: Methods of Testing Emissions (Reference follows data)

The EPA has established National Ambient Air Quality Standards (NAAQS) for air pollutants that endanger public health. Regulations also contain a requirement that the measurement of a regulated air pollutant be done by a specific method. The following 6 "Reference Methods" are set down by the NAAQS (48):

Pollutant	Reference Method
Total Suspended Particulates	High volume samples
Sulfur Dioxide	Pararosaniline (PRA) Method
Carbon Monoxide	Non-dispersive infrared spectrometry (NDIR)
Photochemical Oxidents	Ozone-ethylene Chemiluminescence Reaction
Hydrocarbons	Gas chromatographic separation of methane and flame ionization measurement of non-methane fraction.
Nitrogen Dioxide	Original method replaced by gas phase chemiluminescent procedure.

Test Methods for:

Particulate Concentrations	1) Nephelometer method: Based on light scattering and filter mass (48) 2) Reflectometric method: Based on measurement of reflected light of smoke stain on filter (48)
HC, CO, NO_x	13-mode EPA/CARB Test: (California Air Resources Board) Stationary engine test. (50)
"	CVS (Constant Volume Sampling): obtains mass of exhaust emissions by measuring concentration of the pollutant in the exhaust and mass flow of air through engine. (50)
HC, CO (NO_x cannot be easily measured)	ECE Test (Emission Control of Petrol Engines) (European test). (50)
HC:	Flame Ionization (FID) (49)
CO, NO, HC:	Non-dispersive Infrared (NDIR) (49)
Nitrogen Oxides:	Chemiluminescence Method (49)

Nitrogen Dioxide:	Non-dispersive Ultraviolet (NDUV), Chemi-lumine scence method, Saltzman Method (49)
Formaldehyde:	Chromotropic Method (49)
Total # of Aldehydes:	MBTH Method (3-methyl-2-benzothiazolone hydrozone) (49)
Adehyde & Ketones:	Colorimetric DNPH Method (49)
Exhaust gases:	Bosch-Dunedin Smoke Meter Method (uses a filter which is assessed by a photoelectric reflectometer.) (47)
Sulfur Dioxide:	Pararosaniline Method (47)
Carbon Dioxide:	Always measured by the Non-dispersive, Infrared Absorption Method. (47)
Ozone:	Chemiluminescence Method (47)

APPENDIX E
DATA COLLECTION QUESTIONNAIRE

8 November 1982

SAI-DSL-82-007

Subject: Data Collection for U.S. Army MHE Diesel Engines (35-80 BHP)

Gentlemen:

The U.S. Army Mobility Equipment R&D Command (MERADCOM) has contracted with SAI (DAAK-70-81-D-0031, Task 11) to collect data and perform an evaluation of Reduced Emission/Clean Burning Diesel Engines (RE/CBDEs). These RE/CBDEs would be used in a significant procurement of MHE for use in closed and semi closed environments (ammunition storage, etc).

Although the evaluation is being conducted upon RE/CBDEs, it is the Army's desire to develop a data base of all engines in the 35-80 BHP range. The data collection effort is being conducted to all free world engine manufacturers in order to develop such a data base for future evaluations.

You are invited to participate in this evaluation and data base development by providing data upon the enclosed Diesel Engine Data Sheet (with instructions). One data sheet should be submitted for each candidate engine in the 35-80 BHP range. Additional commercial literature would also be helpful.

The time schedule for the MERADCOM acquisition is such that the data must be provided us by December 15, 1982. Data received after December 15, 1982 will be catalogued but may not be included in the RE/CBDE analysis.

Questions or additional information may be directed to John Daugherty at (703) 821-4347 or Ralph Sievers at (703) 821-4505. The MERADCOM contact is James Stephens, Timothy Lee or Stephen Sousk at (703) 664-4490.

Thank you,

SCIENCE APPLICATIONS, INC.

Phyllis J. Murchland

Phyllis J. Murchland
Program Manager
RE/CBDE Integration
FAX (703) 734-4886
Phone: (703) 734-5942

Enclosures: Diesel Engine Data Sheet
Completion Instructions

Science Applications, Inc. 1710 Goodridge Drive, P.O. Box 1303, McLean, Virginia 22102, (703) 821-4300

Other SAI Offices: Albuquerque, Ann Arbor, Arlington, Atlanta, Boston, Chicago, Huntsville, La Jolla, Los Angeles, Palo Alto, Santa Barbara, Sunnyvale, and Tucson.

MERADCOM Reduced Emission/Clean Burning Diesel Engine Evaluation
(35-80 BHP)

Diesel Engine Data Sheet

* - Explanation on Instruction Sheet
o - Optional Answers

BASIC DATA

1. Corporation: ____________________

2. Manufacturing Entity: ____________________

3. Data Sheet Point of Contact (P.O.C): ____________________

4. P.O.C. Full Telephone Number: ____________________

5. Mailing Address: ____________________
____
____

6. Engine Name/Trademark/Model: ____________________

7. Year Model engine was first sold commercially:
____

o 8. Country(ies) in Which Engine is Currently Being Assembled: __________
____________________ Block Cast: ____________________

9. Design Dimension Basis: (Metric) (Inches) (______________).

o 10. Estimated Approximate Engine Cost in Standard Configuration (Dec. 1982 dollars):

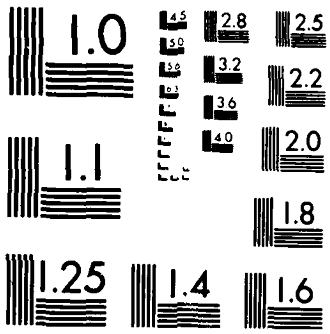
a. Two Engines: $____________________/each
b. 100 Engines/year: $____________________/each
c. 1000 Engines/year: $____________________/each

Please return to:

Mr. John Daugherty (T10-4)
Science Applications, Inc.
1710 Goodridge Drive
P.O. Box 1303
McLean, Virginia 22102

AD-A128 408 REVIEW AND ASSESSMENT OF REDUCED EMISSIONS/CLEAN BURNING DIESEL ENGINES F..(U) SCIENCE APPLICATIONS INC MCLEAN VA J M DAUGHERTY ET AL. 12 MAY 83 SAI-84-170-WA 3/3

UNCLASSIFIED DAAK70-81-D-0031 F/G 21/7 NL



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

PHYSICAL PARAMETERS

11. Cooling: (Air) (Liquid)

12. No. of Cylinders: ______________, Srokes/cycle: ________________,
IL, V, other: ____________________________________.

13. Displacement: (________________ c.i.) or (____________________cc)
Bore and Stroke: (_______x_______in.) or (________x________cm)

14. Compression:

Ratio: __________________ or VCR: ___________________________

15. Injection: (Fuel-Direct) (Fuel-Indirect) (Gas Injection)

16. Combustion Chamber Design: (Open) (Pre-Combustion Ante-Chamber) (Pre-Combustion Divided Chamber) (Air Cell) (Energy Cell) (Lanova Design) (Swirl Design Features: ________________________________)
(Other ____).

17. Design Fuel:

a. Grade: (1-D) (2-D) (4-D) (DF-A); (DF-1) (DF-2) (DF-4); (Class _____ Type _____); (______________________________________).
b. Specification: (ASTM _______) (Fed. Spec VV-F-800) (Bureau of Mines _______________) (DIN _____________) (_______________).
c. Cetane No. ______________________.

18. Alternative Fuels without major engine adjustments:

a. Grade (etc): ____
b. Specifications: ____

19. Type Injectors: Make/Model _____________________________________

a. Standard: (Mechanical) (Electrical)
b. Optional: (Electrical) (Mechanical) (None)
c. Electronic (Computerized) Injector Control Sensory Input: (RPM) (Temperature) (Exhaust Content) (Torque) (______________).
d. Unit Injectors: (yes) (no); (Inline) (Rotary)
e. Fuel Injector Pump (or Unit Injector) Manufacturer: ____________
____
f. Fuel Injector Pump (or Unit Injector) Model:
____.

20. Standard Governor for MHE applications:

a. Manufacturer: ____

b. Model No: ______________________________
c. Type: ______________________________
d. Limits Incorporated ______________________________

____

21. Aspiration:

a. Standard Type: (Naturally Aspirated) (Turbocharged) (Supercharged)
b. Optional Type (If available with same engine model): __________

____

c. Intercooling: (No) (Standard) (Option)

22. Aftercooling: (No) (Standard) (Optional with Same Engine Model)

23. Muffler

a. Standard Type: ______________________________
b. Optional Types: ______________, ______________,

______________________________,

c. Exhaust Backpressure Limits: __________ (cfm) (liters per minute) maximum air flow with pressure differential no greater than __________ (in. H_2) (psi) (______________).
d. Exhaust Treatment: ______________________________.

o 24. Current U.S. Patents (Nos. 3,200,000 and higher) on Engine Design Features: ______________, ______________, ______________, ______________, ______________.

* 25. Weight dry (# or Kg) of Basic Block ______________ #, Kg

with:	Water pump	without: Air cleaner	PS Pump
	Fuel Pump	Oil Filter	Radiates Fan
	Injector Control	Fuel Filter	Alternator
	__________	Water Separator	Starter
	__________	Hydraulic Pump	ATE units
	__________	Flywheel	Sending units
		Bell Housing	__________

Weight # or Kg of Air Cooling Pump and Shroud __________ #, Kg

* 26. Volume (cu ft or cu/cm) of Basic Block ______________ #, Kg
with/without as above.
Flywheel housing diameter ______________ in, cm
Dry Oil Sump (yes) (no)

27. Electrical Starting System
__________ kw Starting motor at __________ V for normal operations
__________ kw Starting motor at __________ V for cold-weather operations
Voltage Systems available 12V, 24V.

28. Current OEM Applications:

	OEM Manufacturer (a)	Product (b)	Model (c)
(1)			
(2)			
(3)			
(4)			
(5)			

OPERATING PARAMETERS

* 29. Use Table on Operating Charcteristics -- Following Page

30. Fuel Used in Performance Tests (Item 62):
(DF-2 results desired. Military logistics diesel fuel)

a. Grade: (1-D) (2-D) (4-D) (DF-A) (DF-1) (DF-2) (DF-4);
(Class ___________ - Type __________) (________________________)
b. Specification: (ASTM _____________) (Fedl. Spec. VV-F-800)
(DIN __________________) (Bureau of Mines) (__________________)
c. CETANE No. ___________________________ (State only if measured)
d. Sulfur Content: _________% (State only if measured)
e. API Gravity: ____________ (State only if measured)
f. Diesel Index: ____________ (State only if measured).

* 31. Noise Level 1-meter from free-standing Engine at Rated Load HP.
_____________ dB with the following accessories.

Air cooling fan ______________________
Water cooling fan ______________________
Alternator ___________________________
Hydraulic Pump ________________________
Power starting pump ___________________
Muffler _______________________
Air Cleaner Filter ________________________

32. Cold Weather Operation

Standard without aids _______________ °F, ___________________ °C
Standard with aids _____________ °F, _____________ °C, Aid: __________
Optional Starting to ________ °F, _________ °C with ________________
Glow Plugs Standard: (yes) (no)

* 33. Emission Characteristics
Use Table on following page

o The instruction sheet contains requests for information pertaining to maintenance and future developments - the provision of this data is optional.

29. Operating Characteristics (13 Mode EPA Diesel Engine Test Cycle)

Test Seg	Mode	Engine Speed	% Torque	BHP[1] ( )	Torque ( )	BMEP ( )	Fuel Consumption (#, Kg/hr)	Fuel Consumption (#, Kg/HPH)	Air Intake Volume ( )	Amb. Temp (C°, F°)	Exhaust Vol. ( )	Exhaust Temp (C°, F°)	Air Press ( )	Noise Level dB at ft, mtr
1	1	Idle	-											
1	2	Inter.	2											
1	3	Inter.	25											
1	4	Inter.	50											
1	5	Inter.	75											
1	6	Inter.	100											
1	7	Idle	-											
2	8	Rated	100											
2	9	↓	75											
2	10	↓	50											
2	11	↓	25											
2	12	↓	2											
2	13	Idle	-											

Method of Measuring:

BHP: ______

Torque: ______

BMEP: ______

Fuel Consumption: ______

Air/Exhaust Temp.: ______

Air Pressure: ______

Noise Level: ______

SAE Test Standard ______ or DIN 6270

[1] Brake Horsepower – A standardized, accepted method must be used. The entry must reflect continuous, flywheel HP, no intermittent or 'souped up' methods, no manual settings, no shaving fins; state if radiator cooling fan was installed on water cooled engines (yes) (no).

33. Emission Characteristics (13 Mode EPA Diesel Engine Test Cycle)

Test Segment	Mode	Eng. Speed	% Torque	BHP ( )	Torque ( )	CO (ppm)	NO_x (ppm)	HC (ppm)	Particulates (mg/HPH)	Bosch Smoke Number	Other Emissions (add as necessary) ( )	( )
1	1	Idle	-									
1	2	Inter.	2									
1	3	Inter.	25									
1	4	Inter.	50									
1	5	Inter.	75									
1	6	Inter.	100									
1	7	Idle	-									
2	8	Rated	100									
2	9		75									
2	10		50									
2	11		25									
2	12		2									
2	13	Idle.	-									

Specify Test Conditions and Standards for:

CO: ______________________________

NO_x: ______________________________

HC: ______________________________

Particulates: ______________________________

Others: ______________________________

____

____

Completion Instructions for Diesel Engine Data Sheet

MERADCOM Reduced Emission/Clean Burning Diesel Engine Evaluation

25. The component weights of the engine candidate must be as equal as is possible among various candidate engines. For this purpose, provide the weight of only the basic, dry block. Eliminate the weight of accessories such as air cleaners, oil and fuel filters, water separators, hydraulic and power steering pumps, fans, alternators and starters, ATE and other sending units, flywheel and bell housing. For air cooled engines, provide a separate weight and cube for the air pump and shroud. Do include water and fuel pumps and injector controls in the weight and cube. The data sheet is organized to assist in the completion of these questions.

26. As with the weight above, volumes must be comparable so the same 'withs' and 'withouts' apply. No flywheel housing must be included in the volume but indicate the diameter of the flywheel housing flange. Also indicate those engines with a dry sump (separate engine oil reservoir).

29. Operating Parameters

This part of the questionnaire gathers operating characteristics of the engine. These characteristics will be based upon the 13-mode diesel engine test cycle defined in the EPA part of the Code of Federal Regulations. Section 26. The tables provided for collecting the data are based upon the 13-mode cycle. You may, however, provide data that you already have available and that will be adjusted as nearly as possible to the 13-mode cycle. It is not intended that you conduct special dynamometer tests to provide the data.

It is important that the data provided be verifiable with some form of certification; also, provide the testing standard. Provide data that you have. Dynamometer runs that you make to gather and provide data are your decisions.

The Army is not looking for 'military ratings' of engines which generally provide increased power capabilities which shorten engine life. The increased (souped-up) power is generally provided with increased RPM, higher compression, more fuel, high ramp cam, etc. The MHE application calls for a long, service-life engine. An appropriate testing standard is the recently released SAI H-1349.

Manufacturers are encouraged to provide graphs of engine characteristics of BHP, Torque, BMEP and specific fuel consumption (fish hooks or envelopes) with marginal data as to test conditions; commercial data would also be appreciated.

The noise level from the engine will not be an evaluation criteria; the total configuration is what counts - fans, pumps, etc; however, the free standing engine noise data is desired.
The EPA 13 Mode Test parameters are listed here: (From CFR 86, 376-79, Diesel Engine Test Cycle).

Test Segment	Mode No.	Engine Speed	Observed Torque % of Max Observed	Time in Mode (minutes) Min.	Max.	Max Cumulative Time (minutes)
1	1	Curb-Idle	—	4.5	6.0	
1	2	Intermediate	2	"	"	
1	3	Intermediate	25	"	"	
1	4	Intermediate	50	"	"	42
1	5	Intermediate	75	"	"	
1	6	Intermediate	100	"	"	
1	7	Curb-Idle	—	"	"	
2	8	Rated	100	"	"	
2	9	Intermediate	75	"	"	
2	10	Intermediate	50	"	"	36
2	11	Intermediate	25	"	"	
2	12	Intermediate	2	"	"	
2	13	Curb-Idle	—	"	"	

31. The noise level is appropriately measured with the engine operating in the MHE vehicle with all accessories in place. It is anticipated tht most free-standing engines will operate at 100-105 dBA and that noise levels will decrease by about 10 dBA when installed in a vehicle. Also, noise-quieting kits are frequently available which may reduce the noise-level 10 additional dBA. Please provide the noise level at one-meter from a free-standing engine under rated load. Also, provide accessories in place in the spaces provided.

ENGINE EMISSION DATA

33. As much emission test data as can be provided are desired. Data on emissions for each of the line entries (or graphical data points) for this would be highly desirable. Data on the indicated emission components (carbon monoxide, CO; total hydrocarbons, HC; nitrogen oxides (NO and NO_2), NO_x; and particulates over a range of BHP at those different speeds most important. The CO, HC, and NO_x are emission components regulated by the U.S. and are therefore those for which test equipment are readily available. Particulate concentration is of special importance for engine usage in closed areas due to smoke obscuration and irritation. More extensive emission data is desirable and columns have been provided for its inclusion in the table. Examples of emission components which would be very useful in consideration of the engine for certain reduced emission applications

are as follows: concentrations of specific hydrocarbon groups (such as the aldehydes) or of specific compounds (such as ethanal (acetaldehyde), propane, methane, etc.); concentration of nitrogen oxide (NO); and concentration of specific particulates (such as SO_4, carbon, etc.) Where extensive engine emission data has been collected (as by Government sponsored testing or by company-sponsored testing at an independent laboratory) provision of a copy of the test report in addition to completion of Item on Table 33 would be greatly appreciated.

RPM, BHP emission data from as many test points as practical are desired. Data of greatest usefulness would be for emissions at the steady-state conditions at which performance data were collected and reported.

Insert emissions data as appropriate. Insert additional column headings and revise units as appropriate to the test data.

Identify standard test reference, e.g. ASTM ________; DIN _______; Code of Federal Regulations Vol 42 No. 174 Sept 8, 77 Subpart D, Section 86. 301-79, (for CO, No_x, and HC); Federal Regulation Vol 46, No. 4, Jan 7, 81, 40 CFR Part 86 (for particulates); an outline of procedures used to collect emissions data, e.g., probe in exhaust outlet-direct reading instrument, filtration-weighing-mass-spectrometry, etc. Identify principal equipment used.

RELIABILITY INFORMATION (Optional Information will be included in file but will not be a part of the data sheet and will not be direct input to recommendations on candidate engines).

You are invited to provide data to which you wish MERADCOM to have ready access to reliability, availability, and maintainability of the engine as a component of OEM (per item 53) or collected separately on the engine. Reliability information of particular concern to the Army are mean time (or miles betwen failure; mean time (or miles) between overhauls; cost of repairs per year, per 1000 miles, etc; mean time to repair; engine design features which expedite or simplify maintenance and repair etc. It is recognized that definitions, test procedures, and data collection may vary widely and therefore is not suited to quantitive comparisons. The concern of the engine manufacturer for the reliability considerations is partially evidenced by the nature and extent of this reliability data collection effort.

You may also provide indications of parts interchangeability with other recently acquired Army equipment using similar engines; also an indication of your world-wide service capability by giving the number of dealers in how many countries.

ANTICIPATED ENGINE IMPROVEMENTS (Optional Information will be included in the file but will not be a part of the data sheet).

Proprietary data to which you wish MERADCOM to have access but which is not to be releasable under the Freedom of Information Act or included in a formal report to MERADCOM should be clearly marked as "Proprietary Data". Do not mark the data sheets as proprietary data. Examples of anticipated engine improvements could be: future capability to use indirect injection head on the otherwise similar engine, computerized engine control based on multiple continuously sensed features (identify) to provide optimum (fuel economy), (emission control), extensive emission testing in progress, regeneration, etc.

APPENDIX F. ENGINE MANUFACTURERS MAILING LIST

MANUFACTURER	RESPONSE	ENGINES RECEIVED	ANALYZED
AIFO Spa-Aifo Motori - Fiat Vias Carducci, 29 20123 Milano, Italy			
Allis Chalmers Corp. Engine Division P.O. Box 563 Harvey, Illinois 60426	Positive	4	None1/
Allis-Chalmers ATTN: Robert Thoreson 1101 17th Street, N.W. Suite 206 Washington, D.C. 20036			
Alsthom-Atlantique/AGROM 38 Avenue Kleber 75784 Paris Cedex 16, France	Negative		
AVCO: Industrial Engine Operation 17220 Park Row Houston, Texas 77084	Positive	11	31/
Allis-Chalmers, Ltd ATTN: Gary T. Nakai Dan Gray 21800 S. Cicero Matteson, Illinois 60443			
Baker Material Handling Corp. ATTN: Edward B. Gutta 5000 Tiedeman Road Cleveland, Ohio 44144			
Brudi Equipment ATTN: Peter Loveland P.O. Box D Kelso, Washington 98632			
J. I. Case ATTN: Bob Scott 700 State Street Racine, Wisconsin 53401			
Caterpillar Defense Products ATTN: G. Griffith Jefferson Bank Building Peoria, Illinois 61629	Positive	None2/	None

APPENDIX F. ENGINE MANUFACTURERS MAILING LIST (Continued)

MANUFACTURER	RESPONSE	ENGINES RECEIVED	ANALYZED
Caterpillar Lift Trucks ATTN: James O. Gray 7800 Tyler Boulevard Mentor, Ohio 44060			
Caterpillar Tractor Company ATTN: E. Bayly Orem, Jr. 1850 K Street Washington, D.C. 20006			
Clark Equipment A.G. ATTN: Tom Hill Jim Pacetti Dean Stetler P.O. Box 1320 Battle Creek, Michigan 49016			
CLM-Societe Commerical de Moteurs BP 420 (Peugeot Citroen) 92004 Nanterra Cedex, France			
Cummins Engine Company ATTN: Louis C. Broering 1000 Fifth Street Columbia, Indiana 47201	Positive	None	None
DAF Diesel Postbus 1055 5602 BB Eindhove The Netherlands			
Datsun Engine Division Nissan Industrial Equipment Company 2900 Datsun Drive P.O. Box 161404 Memphis, Tennessee 38116			
Deere and Company John Deere OEM Sales John Deere Road Moline, Illinois 61265	Positive	5	5
Detroit Diesel Allison Division 13400 W. Outer Drive Detroit, Michigan 48228			
Deutz Corporation 7585 Ponce de Leon Circle Atlanta, Georgia 30340	Positive		

APPENDIX F. ENGINE MANUFACTURERS MAILING LIST (Continued)

MANUFACTURER	RESPONSE	ENGINES RECEIVED	ANALYZED
Deutz Corporation ATTN: Peter H. Cerf 6712 Woodale Avenue Edina, Minnesota 55435	Positive	5	5
Drexel Ind. Inc. ATTN:Guido A. Donato E. M. Wishing Horsham, Pennsylvania			
Energy Applications, Inc. 224 Long Reach Village Center Columbia, Maryland 21045			
Exide Corporation ATTN: James B. Coker 9176 Red Branch Road Columbia, Maryland 21045	Negative		
Pegao - E.N.A.S.A Jose Abascal 2 Madrid, Spain			
Eston Corporation ATTN: R. G. Becker 11000 Roosevelt Boulevard Philadelphia, PA 19115			
Ford Motor Company Ford Industrial Engine Operations Suite 1800 300 Renaissance Center P.O. Box 43338 Detroit, Michigan 48243	Positive	6	2[1]
Ford Tractor Operation ATTN: Frank Druzynski Troy, Michigan 48084			
GEC Diesels Limited Vulcan Works Newton-le Willows Merseyside England WA 128RU	Negative		

APPENDIX F. ENGINE MANUFACTURERS MAILING LIST (Continued)

MANUFACTURER	RESPONSE	ENGINES RECEIVED	ANALYZED
Hatz Diesel Motorenfabrik Hatz GMBH & Co. KG Ruhstorf Rott Federal Republic of Germany D-8300 Ruhstorf a.d. Rott	Positive	13	4 1/ 3/
Hatz Diesel of America, Inc. 2867 South 160th Street New Berlin, Wisconsin 53151			
Hawker Siddeley Lister Diesels 555 East 56 Highway Olathe, Kansas 66061			
Hino Motors, Ltd. Marketing Research & Sales Promotion Dept. 1-7-17 Nihonbashi, Chuo-Ku Tokyo, Japan			
Hyster Company ATTN: Duane Kragrud Portland, Oregon			
Industrial Trucking Association ATTN: Mark J. Weissert 1326 Freeport Road Pittsburg, Pennsylvania 15238			
International Harvester Marketing Department Engine Division 401 N. Michigan Avenue Chicago, Illinois 60611			
Isuzu Motors Ltd 22-10, Minamioi 6-Chome Shinagawa-Ku, Tokyo 140, Japan	Positive	3	3
Jenbacher Werke Ag Achenseestyrasse 1-3 6200 Jenback, Austria			

APPENDIX F. ENGINE MANUFACTURERS MAILING LIST (Continued)

MANUFACTURER	RESPONSE	ENGINES RECEIVED	ANALYZED
KHD Canada, Inc. ATTN: J. E. Sauerteig 4660 Hickmore Montreal Canada H4T 1K2			
Kirloskara Inc. USA Western Hemisphere Office 1501 Cherry Hill Road Baltimore, Maryland 21225			
Kubota Tractor Corp., Eng Div 391 Krossen Avenue P.O. Box 1124 Elk Grove Village, Illinois	Positive	8	2[1/]
Kubota, Ltd., Farm & Industrial Machinery Division 2-47, Shikitsu Higashi 1-Chome Naniwa-Ku, Osaka 556-91 Japan			
Leyland Vehicles Limited Leyland Power Systems, Division Sales and Marketing Headquarters Guild Center Preston, Lancashire, England			
Lombardini Motori SpA P.O. Box 5 42100 Reggio Emilia, Italy			
Man-Maschinenfabrik Augsburg-Nurnberg AG Stradtbachstr.1 8900 Augsburg Federal Republic of Germany	Negative		
MWM-Motoren-Werke Mannheim AG Carl-Benz-Strasse P.O. Box 1563 6800 Mannheim 1 Federal Republic of Germany			
Mazda, Toyo Kogyo Co. Ltd. 3-1 Shinchi, Fuchu-Cho Aki-Gun, Hiroshima, Japan	Positive	3	None[4/]

APPENDIX F. ENGINE MANUFACTURERS MAILING LIST (Continued)

MANUFACTURER	RESPONSE	ENGINES RECEIVED	ANALYZED
Perkins Engines Company ATTN:Ken Galloway Peterborough PEI 5NA England 073367474			
Petters Limited England PJ4 Staines, Middlesex TW183AR, England			
Pettibone ATTN: R. T. Tiebout 4720 Montgomery Lane Bethesda, Maryland 20814			
Peugeot-Citroen, Ste Commericale de Moteurs-CLM BP 420, 49 Rue Noel-PONS 92004 Nanterre Cedex, France	Positive	1	None1/
Regie Nationale des Usines Renault Division Renault Moteurs La Boursidiere-R.N. 186 92357 Le Plessis Robinson Cedex France			
SOFIM-Societa Franco Italiana di Motori S.p.A. Casella Postale 186 71100 Foggia Incoronata, Italy			
Same Trattori S.P.A. 20156 Milano Piazzale Accursio, 18 Italy			
Silent Hoist and Crane Company ATTN: Robert E. Cohen 841 63rd Street Brooklyn, New York 11220	Negative		
Slanzi of North America Inc. Shingle Creek Parkway Minneapolis, Minnesota 55430			
Stabilimenti Meccanici S.p.A. (UM Group) Via Ferrarese, 29 44042 Cento (Ferrara) Italy			

APPENDIX F. ENGINE MANUFACTURERS MAILING LIST (Continued)

MANUFACTURER	RESPONSE	ENGINES RECEIVED	ANALYZED
Sterling Engine Co., Inc. 3600 N.W. North River Drive Miami, Florida			
Stewart & Stevenson Services, Inc. P.O. Box 1637 Houston, Texas 77001	Negative		
Steyr-Daimler-Puch Ag Schomauerstr.5 4400 Steyr, Austria			
Teledyne Continental Motors Industrial Products Division 700 Terrace Street Muskegon, Michigan 49443	Positive	1	1
Valmet Oy Linnayuori Works 37240 Linnavuori, Finland			
Volkswagon Industrial Engines Division Volkswagon of America, Inc. 3737 Lake-Cook Road Deerfield, Illinois 60015			
Volvo Penta AB 405 08 Gothenburg, Sweden			
Waukesha Engines ATTN: F. B. Reid Suite 316 7310 Ritchie Highway Glen Burnie, Maryland 21061			
Waukesha Engine Division, ATTN: Tom Nottingham Dresser Industries, Inc. 1000 W. St. Paul Avenue Waukesha, Wisconsin 53187			
Werres/Raymond Corporation ATTN: Karl Millter 12022 Parklawn Drive Rockville, Maryland 20852			

APPENDIX F. ENGINE MANUFACTURERS MAILING LIST (Continued)

MANUFACTURER	RESPONSE	ENGINES RECEIVED	ANALYZED
White Engines, Inc. P.O. Box 6904 Canton, Ohio 44706	Positive	3	None 1/
Yanmar Diesel Engine Co. Ltd 1-1, 2-Chome, Yaesu Chuo-Ku, Tokyo 104, Japan			

1/ Detailed emission data not provided for all engines

2/ Does not manufacture engines in the 30-60 HP range

3/ Some engines were at the limit of the horsepower range we were considering and consequently were not examined in detail.

4/ These are Perkins Engines manufactured in Japan

APPENDIX G

SUMMARY QUESTIONNAIRE DATA

Note: The term "rated loads" used in this section are defined as:

The percent torque produced at hosepower and RPM. All loads except idle are at rated RPM. (Detailed calculations are shown in Chapter 5).

]

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: AVCO

ENGINE MODEL NUMBER: HR 692 HTA (TEST)

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 4.2

HORSEPOWER @ 25%= 32.4

HORSEPOWER @ 50%= 67.8

HORSEPOWER @ 75%= 97.6

HORSEPOWER @ 100%= 128.6

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.32

FUEL CONSUMPTION @ 2%= 18.6

FUEL CONSUMPTION @ 25%= 26.22

FUEL CONSUMPTION @ 50%= 36.00

FUEL CONSUMPTION @ 75%= 46.02

FUEL CONSUMPTION @ 100%= 59.22

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 26,7,13

CO,NOX,HC @ 2%= 37,254,8

CO,NOX,HC @ 25%= 46,371,10

CO,NOX,HC @ 50%= 67,416,13

CO,NOX,HC @ 75%= 82,429,17

CO,NOX,HC @ 100%= 107,390,16

#1

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : AVCO
MODEL NUMBER : HR 692 HTA (TEST)
RATED HORSEPOWER(TEST) = 128.6

3589 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=20.842766
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=24.2204255
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=27.6289831
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=31.0823729

AT 12.5 HORSEPOWER CO(GM/HR)=39.6489362
AT 25 HORSEPOWER CO(GM/HR)=43.6382979
AT 37.5 HORSEPOWER CO(GM/HR)=49.0254237
AT 50 HORSEPOWER CO(GM/HR)=56.440678

AT 12.5 HORSEPOWER NOX(GM/HR)=288.43617
AT 25 HORSEPOWER NOX(GM/HR)=340.297872
AT 37.5 HORSEPOWER NOX(GM/HR)=377.483051
AT 50 HORSEPOWER NOX(GM/HR)=393.372881

AT 12.5 HORSEPOWER HC(GM/HR)=8.58865248
AT 25 HORSEPOWER HC(GM/HR)=9.47517731
AT 37.5 HORSEPOWER HC(GM/HR)=10.4322034
AT 50 HORSEPOWER HC(GM/HR)=11.4915254

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 104 (KGM) = 47

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 238

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1438

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 66

]

#1

```
RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: AVCO

ENGINE MODEL NUMBER: HR 492 HT(ESTIMATE)

***********************INPUT TEST DATA**********************

 INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

 HORSEPOWER @ 2%= 2.8

 HORSEPOWER @ 25%= 22.0

 HORSEPOWER @ 50%= 45.0

 HORSEPOWER @ 75%= 65.0

 HORSEPOWER @ 100%= 85.0

 INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

 FUEL CONSUMPTION @ IDLE= 0.88

 FUEL CONSUMPTION @ 2%= 12.39

 FUEL CONSUMPTION @ 25%= 17.48

 FUEL CONSUMPTION @ 50%= 24.00

 FUEL CONSUMPTION @ 75%= 30.68

 FUEL CONSUMPTION @ 100%= 39.48

 INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

 CO,NOX,HC @ IDLE= 17,5,9

 CO,NOX,HC @ 2%= 25,169,5

 CO,NOX,HC @ 25%= 31,247,7

 CO,NOX,HC @ 50%= 45,277,9

 CO,NOX,HC @ 75%= 55,286,11

 CO,NOX,HC @ 100%= 71,260,11
```


2

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : AVCO
MODEL NUMBER : HR 492 HT(ESTIMATE)
RATED HORSEPOWER(TEST) = 85

2393 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=14.9615104
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=18.3304348
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=21.873913
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=25.67

AT 12.5 HORSEPOWER CO(GM/HR)=28.03125
AT 25 HORSEPOWER CO(GM/HR)=32.826087
AT 37.5 HORSEPOWER CO(GM/HR)=40.4347826
AT 50 HORSEPOWER CO(GM/HR)=47.5

AT 12.5 HORSEPOWER NOX(GM/HR)=208.40625
AT 25 HORSEPOWER NOX(GM/HR)=250.913044
AT 37.5 HORSEPOWER NOX(GM/HR)=267.217391
AT 50 HORSEPOWER NOX(GM/HR)=279.25

AT 12.5 HORSEPOWER HC(GM/HR)=6.01041667
AT 25 HORSEPOWER HC(GM/HR)=7.26086957
AT 37.5 HORSEPOWER HC(GM/HR)=8.34782609
AT 50 HORSEPOWER HC(GM/HR)=9.5

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 78 (KGM) = 35

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 173

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1052

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 48

]

#2

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: AVCO

ENGINE MODEL NUMBER: HR 392 HT(ESTIMATE)

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 2.1

HORSEPOWER @ 25%= 16.2

HORSEPOWER @ 50%= 33.9

HORSEPOWER @ 75%= 48.8

HORSEPOWER @ 100%= 64.3

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 0.66

FUEL CONSUMPTION @ 2%= 9.30

FUEL CONSUMPTION @ 25%= 13.11

FUEL CONSUMPTION @ 50%= 18.00

FUEL CONSUMPTION @ 75%= 23.01

FUEL CONSUMPTION @ 100%= 29.61

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 13,4,6

CO,NOX,HC @ 2%= 19,127,4

CO,NOX,HC @ 25%= 23,185,5

CO,NOX,HC @ 50%= 33,208,6

CO,NOX,HC @ 75%= 41,214,8

CO,NOX,HC @ 100%= 53,195,8

3

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : AVCO
MODEL NUMBER : HR 392 HT(ESTIMATE)
RATED HORSEPOWER(TEST) = 64.3

1800 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=12.1102128
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=15.5411864
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=19.2104698
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=23.5209678

AT 12.5 HORSEPOWER CO(GM/HR)=21.9503546
AT 25 HORSEPOWER CO(GM/HR)=27.9717514
AT 37.5 HORSEPOWER CO(GM/HR)=34.9328859
AT 50 HORSEPOWER CO(GM/HR)=41.9290323

AT 12.5 HORSEPOWER NOX(GM/HR)=169.780142
AT 25 HORSEPOWER NOX(GM/HR)=196.435028
AT 37.5 HORSEPOWER NOX(GM/HR)=209.449664
AT 50 HORSEPOWER NOX(GM/HR)=212.529032

AT 12.5 HORSEPOWER HC(GM/HR)=4.73758865
AT 25 HORSEPOWER HC(GM/HR)=5.49717514
AT 37.5 HORSEPOWER HC(GM/HR)=6.48322148
AT 50 HORSEPOWER HC(GM/HR)=8

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 66 (KGM) = 30

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 143

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 830

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 35

]

3

```
RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: CONTINENTAL

ENGINE MODEL NUMBER: TMD 2.7 LITRENGINE

**********************INPUT TEST DATA**********************

 INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

 HORSEPOWER @ 2%= 1.2

 HORSEPOWER @ 25%= 15.0

 HORSEPOWER @ 50%= 30.9

 HORSEPOWER @ 75%= 45.7

 HORSEPOWER @ 100%= 61.4

 INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

 FUEL CONSUMPTION @ IDLE= 0.7

 FUEL CONSUMPTION @ 2%= 6.5

 FUEL CONSUMPTION @ 25%= 10.7

 FUEL CONSUMPTION @ 50%= 14.9

 FUEL CONSUMPTION @ 75%= 19.9

 FUEL CONSUMPTION @ 100%= 27.1

 INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

 CO,NOX,HC @ IDLE= 11,3,4

 CO,NOX,HC @ 2%= 98,16,28

 CO,NOX,HC @ 25%= 54,53,11

 CO,NOX,HC @ 50%= 33,113,3

 CO,NOX.HC @ 75%= 37,163,3

 CO,NOX,HC @ 100%= 104,500,6
                       178
```

#4

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

  COMPUTED DATA FOR ENGINE:
    MANUFACTURED BY : CONTINENTAL
    MODEL NUMBER : TMD 2.7 LITRENGINE
    RATED HORSEPOWER(TEST) = 61.4

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=9.93913043
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.3415094
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=17.1297297
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=21.8719745


AT 12.5 HORSEPOWER CO(GM/HR)=61.9710145
AT 25 HORSEPOWER CO(GM/HR)=40.7924528
AT 37.5 HORSEPOWER CO(GM/HR)=34.7837838
AT 50 HORSEPOWER CO(GM/HR)=55.3503185


AT 12.5 HORSEPOWER NOX(GM/HR)=46.2971015
AT 25 HORSEPOWER NOX(GM/HR)=90.7358492
AT 37.5 HORSEPOWER NOX(GM/HR)=135.297297
AT 50 HORSEPOWER NOX(GM/HR)=167.10828


AT 12.5 HORSEPOWER HC(GM/HR)=14.0797101
AT 25 HORSEPOWER HC(GM/HR)=5.96855346
AT 37.5 HORSEPOWER HC(GM/HR)=3
AT 50 HORSEPOWER HC(GM/HR)=3.82165605


FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
   1.7 HR. ENGINE OFF
   2.0 HR. ENGINE @ IDLE
   1.0 HR. ENGINE @ 12.5 HP
   3.0 HR. ENGINE @ 25.0 HP
   0.2 HR. ENGINE @ 37.5 HP
   0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 56 (KGM) = 25

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 218

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 368

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 40

]
```

2700 cc

#4

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: JOHN DEERE

ENGINE MODEL NUMBER: 4276 DF

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.6

HORSEPOWER @ 25%= 20.0

HORSEPOWER @ 50%= 40.0

HORSEPOWER @ 75%= 60.0

HORSEPOWER @ 100%= 80.0

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 2.16

FUEL CONSUMPTION @ 2%= 2.47

FUEL CONSUMPTION @ 25%= 10.84

FUEL CONSUMPTION @ 50%= 18.94

FUEL CONSUMPTION @ 75%= 25.64

FUEL CONSUMPTION @ 100%= 33.93

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 40,25,29

CO,NOX,HC @ 2%= 222,85,131

CO,NOX,HC @ 25%= 164,167,97

CO,NOX,HC @ 50%= 105,410,77

CO,NOX,HC @ 75%= 94,708,67

CO,NOX,HC @ 100%= 437,975,44

#5

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : JOHN DEERE
MODEL NUMBER : 4276 DF
RATED HORSEPOWER(TEST) = 80

4520 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=7.42831522
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=12.865
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=17.9275
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=22.29

AT 12.5 HORSEPOWER CO(GM/HR)=187.641304
AT 25 HORSEPOWER CO(GM/HR)=149.25
AT 37.5 HORSEPOWER CO(GM/HR)=112.375
AT 50 HORSEPOWER CO(GM/HR)=99.5

AT 12.5 HORSEPOWER NOX(GM/HR)=133.576087
AT 25 HORSEPOWER NOX(GM/HR)=227.75
AT 37.5 HORSEPOWER NOX(GM/HR)=379.625
AT 50 HORSEPOWER NOX(GM/HR)=559

AT 12.5 HORSEPOWER HC(GM/HR)=110.858696
AT 25 HORSEPOWER HC(GM/HR)=92
AT 37.5 HORSEPOWER HC(GM/HR)=79.5
AT 50 HORSEPOWER HC(GM/HR)=72

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 56 (KGM) = 25

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 747

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 998

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 467

]

#5

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: JOHNDEERE

ENGINE MODEL NUMBER: 4239 DF

**********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.5

HORSEPOWER @ 25%= 19.Ø

HORSEPOWER @ 5Ø%= 38.Ø

HORSEPOWER @ 75%= 56.Ø

HORSEPOWER @ 1ØØ%= 75.Ø

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.76

FUEL CONSUMPTION @ 2%= 1.83

FUEL CONSUMPTION @ 25%= 11.68

FUEL CONSUMPTION @ 5Ø%= 16.75

FUEL CONSUMPTION @ 75%= 22.49

FUEL CONSUMPTION @ 1ØØ%= 29.76

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 34,19,24

CO,NOX,HC @ 2%= 234,43,117

CO,NOX,HC @ 25%= 172,1Ø9,57

CO,NOX,HC @ 5Ø%= 1Ø2,241,46

CO,NOX,HC @ 75%= 91,413,3Ø

CO,NOX,HC @ 1ØØ%= 278,749,2Ø

6

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : JOHNDEERE
MODEL NUMBER : 4239 DF
RATED HORSEPOWER(TEST) = 75

3920 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.02142857
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.2810526
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.616579
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=20.5766667

AT 12.5 HORSEPOWER CO(GM/HR)=195.028571
AT 25 HORSEPOWER CO(GM/HR)=149.894737
AT 37.5 HORSEPOWER CO(GM/HR)=103.842105
AT 50 HORSEPOWER CO(GM/HR)=94.6666667

AT 12.5 HORSEPOWER NOX(GM/HR)=84.4857143
AT 25 HORSEPOWER NOX(GM/HR)=150.684211
AT 37.5 HORSEPOWER NOX(GM/HR)=237.526316
AT 50 HORSEPOWER NOX(GM/HR)=355.666667

AT 12.5 HORSEPOWER HC(GM/HR)=85.5714286
AT 25 HORSEPOWER HC(GM/HR)=60.3684211
AT 37.5 HORSEPOWER HC(GM/HR)=46.5526316
AT 50 HORSEPOWER HC(GM/HR)=35.3333333

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 56 (KGM) = 25

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 742

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 657

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 327

]

#6

```
 RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: JOHN DEERE

ENGINE MODEL NUMBER: 4219 DF

**********************INPUT TEST DATA**********************

 INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

 HORSEPOWER @ 2%= 1.4

 HORSEPOWER @ 25%= 18.Ø

 HORSEPOWER @ 5Ø%= 35.Ø

 HORSEPOWER @ 75%= 53.Ø

 HORSEPOWER @ 1ØØ%= 7Ø.Ø

 INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

 FUEL CONSUMPTION @ IDLE= 2.ØØ

 FUEL CONSUMPTION @ 2%= 3.Ø2

 FUEL CONSUMPTION @ 25%= 12.19

 FUEL CONSUMPTION @ 5Ø%= 16.69

 FUEL CONSUMPTION @ 75%= 22.57

 FUEL CONSUMPTION @ 1ØØ%= 29.23

 INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

 CO,NOX,HC @ IDLE= 32,19,35

 CO,NOX,HC @ 2%= 22Ø,3Ø,179

 CO,NOX,HC @ 25%= 165,91,1Ø7

 CO,NOX,HC @ 5Ø%= 92,232,67

 CO,NOX,HC @ 75%= 61,453,62

 CO,NOX,HC @ 1ØØ%= 245,655,36
```

#7

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : JOHN DEERE
MODEL NUMBER : 4219 DF
RATED HORSEPOWER(TEST) = 70

3600 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=9.15174699
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=14.0429412
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=17.5066667
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=21.59

AT 12.5 HORSEPOWER CO(GM/HR)=183.222892
AT 25 HORSEPOWER CO(GM/HR)=134.941176
AT 37.5 HORSEPOWER CO(GM/HR)=87.6944445
AT 50 HORSEPOWER CO(GM/HR)=66.1666667

AT 12.5 HORSEPOWER NOX(GM/HR)=70.7891566
AT 25 HORSEPOWER NOX(GM/HR)=149.058824
AT 37.5 HORSEPOWER NOX(GM/HR)=262.694444
AT 50 HORSEPOWER NOX(GM/HR)=416.166667

AT 12.5 HORSEPOWER HC(GM/HR)=130.855422
AT 25 HORSEPOWER HC(GM/HR)=90.5294118
AT 37.5 HORSEPOWER HC(GM/HR)=66.3055555
AT 50 HORSEPOWER HC(GM/HR)=62.8333333

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 60 (KGM) = 27

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 676

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 650

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 491

]

#7

```
RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: JOHN DEERE

ENGINE MODEL NUMBER: 3179 DF

**********************INPUT TEST DATA**********************

 INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

 HORSEPOWER @ 2%= 1.1

 HORSEPOWER @ 25%= 14.0

 HORSEPOWER @ 50%= 28.0

 HORSEPOWER @ 75%= 42.0

 HORSEPOWER @ 100%= 56.0

 INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

 FUEL CONSUMPTION @ IDLE= 1.43

 FUEL CONSUMPTION @ 2%= 1.45

 FUEL CONSUMPTION @ 25%= 9.48

 FUEL CONSUMPTION @ 50%= 13.16

 FUEL CONSUMPTION @ 75%= 18.23

 FUEL CONSUMPTION @ 100%= 24.49

 INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

 CO,NOX,HC @ IDLE= 26,23,14

 CO,NOX,HC @ 2%= 88,76,51

 CO,NOX,HC @ 25%= 67,93,49

 CO,NOX,HC @ 50%= 57,305,48

 CO,NOX,HC @ 75%= 52,407,41

 CO,NOX,HC @ 100%= 294,576,31
```

8

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : JOHN DEERE
MODEL NUMBER : 3179 DF
RATED HORSEPOWER(TEST) = 56 2940 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.54627908
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=12.3714286
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.6003571
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=21.8071429

AT 12.5 HORSEPOWER CO(GM/HR)=69.4418605
AT 25 HORSEPOWER CO(GM/HR)=59.1428572
AT 37.5 HORSEPOWER CO(GM/HR)=53.6071429
AT 50 HORSEPOWER CO(GM/HR)=190.285714

AT 12.5 HORSEPOWER NOX(GM/HR)=91.0232559
AT 25 HORSEPOWER NOX(GM/HR)=259.571429
AT 37.5 HORSEPOWER NOX(GM/HR)=374.214286
AT 50 HORSEPOWER NOX(GM/HR)=503.571429

AT 12.5 HORSEPOWER HC(GM/HR)=49.2325581
AT 25 HORSEPOWER HC(GM/HR)=48.2142857
AT 37.5 HORSEPOWER HC(GM/HR)=43.25
AT 50 HORSEPOWER HC(GM/HR)=35.2857143

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 54 (KGM) = 24

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 328

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1040

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 234

]

#8

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: JOHN DEERE

ENGINE MODEL NUMBER: 3164 DF

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.0

HORSEPOWER @ 25%= 13.0

HORSEPOWER @ 50%= 26.0

HORSEPOWER @ 75%= 39.0

HORSEPOWER @ 100%= 52.0

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 0.77

FUEL CONSUMPTION @ 2%= 1.43

FUEL CONSUMPTION @ 25%= 8.59

FUEL CONSUMPTION @ 50%= 12.35

FUEL CONSUMPTION @ 75%= 17.00

FUEL CONSUMPTION @ 100%= 24.12

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 31,15,28

CO,NOX,HC @ 2%= 119,78,66

CO,NOX,HC @ 25%= 86,172,61

CO,NOX,HC @ 50%= 57,375,57

CO,NOX,HC @ 75%= 52,704,52

CO,NOX,HC @ 100%= 381,782,38

#9

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : JOHN DEERE
MODEL NUMBER : 3164 DF
RATED HORSEPOWER(TEST) = 52

2690 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.29166667
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=12.0607692
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.4634615
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=23.0246154

AT 12.5 HORSEPOWER CO(GM/HR)=87.375
AT 25 HORSEPOWER CO(GM/HR)=59.2307692
AT 37.5 HORSEPOWER CO(GM/HR)=52.5769231
AT 50 HORSEPOWER CO(GM/HR)=330.384616

AT 12.5 HORSEPOWER NOX(GM/HR)=168.083333
AT 25 HORSEPOWER NOX(GM/HR)=359.384615
AT 37.5 HORSEPOWER NOX(GM/HR)=666.038462
AT 50 HORSEPOWER NOX(GM/HR)=770

AT 12.5 HORSEPOWER HC(GM/HR)=61.2083333
AT 25 HORSEPOWER HC(GM/HR)=57.3076923
AT 37.5 HORSEPOWER HC(GM/HR)=52.5769231
AT 50 HORSEPOWER HC(GM/HR)=40.1538462

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 51 (KGM) = 23

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 370

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1486

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 303

]

#9

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: DEUTZ

ENGINE MODEL NUMBER: F4L 912

***********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.2

HORSEPOWER @ 25%= 21.1

HORSEPOWER @ 50%= 42.1

HORSEPOWER @ 75%= 52.6

HORSEPOWER @ 100%= 73.7

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.32

FUEL CONSUMPTION @ 2%= 8.38

FUEL CONSUMPTION @ 25%= 11.90

FUEL CONSUMPTION @ 50%= 17.86

FUEL CONSUMPTION @ 75%= 20.72

FUEL CONSUMPTION @ 100%= 28.66

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 35,49,17

CO,NOX,HC @ 2%= 98,184,53

CO,NOX,HC @ 25%= 84,322,63

CO,NOX,HC @ 50%= 73,554,62

CO,NOX,HC @ 75%= 97,937,53

CO,NOX,HC @ 100%= 554,1090,51

#10

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : DEUTZ
MODEL NUMBER : F4L 912
RATED HORSEPOWER(TEST) = 73.7

3770 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=10.3395876
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.0068571
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.5544762
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=20.0118095

AT 12.5 HORSEPOWER CO(GM/HR)=90.2061856
AT 25 HORSEPOWER CO(GM/HR)=81.9571429
AT 37.5 HORSEPOWER CO(GM/HR)=75.4095238
AT 50 HORSEPOWER CO(GM/HR)=91.0571429

AT 12.5 HORSEPOWER NOX(GM/HR)=260.824742
AT 25 HORSEPOWER NOX(GM/HR)=365.085715
AT 37.5 HORSEPOWER NOX(GM/HR)=503.180953
AT 50 HORSEPOWER NOX(GM/HR)=842.161905

AT 12.5 HORSEPOWER HC(GM/HR)=58.5670103
AT 25 HORSEPOWER HC(GM/HR)=62.8142857
AT 37.5 HORSEPOWER HC(GM/HR)=62.2190476
AT 50 HORSEPOWER HC(GM/HR)=55.2285715

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 57 (KGM) = 25

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 430

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1638

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 298

]

#10

```
RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: DEUTZ

ENGINE MODEL NUMBER: F4L 912W

**********************INPUT TEST DATA**********************

 INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

 HORSEPOWER @ 2%= 4.7

 HORSEPOWER @ 25%= 21.1

 HORSEPOWER @ 50%= 31.5

 HORSEPOWER @ 75%= 52.9

 HORSEPOWER @ 100%= 62.2

 INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

 FUEL CONSUMPTION @ IDLE= 1.54

 FUEL CONSUMPTION @ 2%= 8.16

 FUEL CONSUMPTION @ 25%= 12.57

 FUEL CONSUMPTION @ 50%= 15.65

 FUEL CONSUMPTION @ 75%= 22.93

 FUEL CONSUMPTION @ 100%= 27.34

 INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

 CO,NOX,HC @ IDLE= 10,22,2

 CO,NOX,HC @ 2%= 43,95,8

 CO,NOX,HC @ 25%= 29,196,7

 CO,NOX,HC @ 50%= 25,251,6

 CO,NOX,HC @ 75%= 27,335,6

 CO,NOX,HC @ 100%= 32,330,5
```

11

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : DEUTZ
MODEL NUMBER : F4L 912W
RATED HORSEPOWER(TEST) = 62.2

3770 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=10.257439
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.725
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=17.6911215
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=21.9434579

AT 12.5 HORSEPOWER CO(GM/HR)=36.3414634
AT 25 HORSEPOWER CO(GM/HR)=27.5
AT 37.5 HORSEPOWER CO(GM/HR)=25.5607477
AT 50 HORSEPOWER CO(GM/HR)=26.728972

AT 12.5 HORSEPOWER NOX(GM/HR)=143.036585
AT 25 HORSEPOWER NOX(GM/HR)=216.625
AT 37.5 HORSEPOWER NOX(GM/HR)=274.551402
AT 50 HORSEPOWER NOX(GM/HR)=323.616823

AT 12.5 HORSEPOWER HC(GM/HR)=7.52439025
AT 25 HORSEPOWER HC(GM/HR)=6.625
AT 37.5 HORSEPOWER HC(GM/HR)=6
AT 50 HORSEPOWER HC(GM/HR)=6

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 60 (KGM) = 27

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 146

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 924

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 33

]

#11

RUN

**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: DEUTZ

ENGINE MODEL NUMBER: F3L 912

**********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.4

HORSEPOWER @ 25%= 15.8

HORSEPOWER @ 50%= 31.6

HORSEPOWER @ 75%= 39.5

HORSEPOWER @ 100%= 55.3

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 0.99

FUEL CONSUMPTION @ 2%= 6.39

FUEL CONSUMPTION @ 25%= 9.04

FUEL CONSUMPTION @ 50%= 13.45

FUEL CONSUMPTION @ 75%= 15.87

FUEL CONSUMPTION @ 100%= 21.83

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 25,37,13

CO,NOX,HC @ 2%= 70,149,42

CO,NOX,HC @ 25%= 57,260,44

CO,NOX,HC @ 50%= 64,418,42

CO,NOX,HC @ 75%= 84,690,39

CO,NOX,HC @ 100%= 480,788,37

#12

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : DEUTZ
MODEL NUMBER : F3L 912
RATED HORSEPOWER(TEST) = 55.3

2827 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.43270834
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=11.6078481
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=15.2573418
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=19.8307595

AT 12 5 HORSEPOWER CO(GM/HR)=59.9791667
AT 25 HORSEPOWER CO(GM/HR)=61.0759494
AT 37.5 HORSEPOWER CO(GM/HR)=78.9367089
AT 50 HORSEPOWER CO(GM/HR)=347.164557

AT 12.5 HORSEPOWER NOX(GM/HR)=234.5625
AT 25 HORSEPOWER NOX(GM/HR)=352
AT 37.5 HORSEPOWER NOX(GM/HR)=621.13924
AT 50 HORSEPOWER NOX(GM/HR)=755.126582

AT 12.5 HORSEPOWER HC(GM/HR)=43.5416667
AT 25 HORSEPOWER HC(GM/HR)=42.835443
AT 37.5 HORSEPOWER HC(GM/HR)=39.7594937
AT 50 HORSEPOWER HC(GM/HR)=37.6708861

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 50 (KGM) = 22

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 343

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1564

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 209

]

12

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: DEUTZ

ENGINE MODEL NUMBER: F3L 913G

***********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.0

HORSEPOWER @ 25%= 12.4

HORSEPOWER @ 50%= 23.8

HORSEPOWER @ 75%= 39.8

HORSEPOWER @ 100%= 50.3

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.01

FUEL CONSUMPTION @ 2%= 4.69

FUEL CONSUMPTION @ 25%= 7.85

FUEL CONSUMPTION @ 50%= 11.31

FUEL CONSUMPTION @ 75%= 16.16

FUEL CONSUMPTION @ 100%= 19.75

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 23,26,9

CO,NOX,HC @ 2%= 50,40,31

CO,NOX,HC @ 25%= 48,86,29

CO,NOX,HC @ 50%= 40,97,28

CO,NOX,HC @ 75%= 37,219,24

CO,NOX,HC @ 100%= 51,325,22

13

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : DEUTZ
MODEL NUMBER : F3L 913G
RATED HORSEPOWER(TEST) = 50.3

3064 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=7.88035088
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=11.67375
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=15.4628125
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=19.6474286

AT 12.5 HORSEPOWER CO(GM/HR)=47.9298246
AT 25 HORSEPOWER CO(GM/HR)=39.775
AT 37.5 HORSEPOWER CO(GM/HR)=37.43125
AT 50 HORSEPOWER CO(GM/HR)=50.6

AT 12.5 HORSEPOWER NOX(GM/HR)=86.0964912
AT 25 HORSEPOWER NOX(GM/HR)=106.15
AT 37.5 HORSEPOWER NOX(GM/HR)=201.4625
AT 50 HORSEPOWER NOX(GM/HR)=321.971429

AT 12.5 HORSEPOWER HC(GM/HR)=28.9912281
AT 25 HORSEPOWER HC(GM/HR)=27.7
AT 37.5 HORSEPOWER HC(GM/HR)=24.575
AT 50 HORSEPOWER HC(GM/HR)=22.0571429

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 49 (KGM) = 22

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 225

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 529

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 137

]

13

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: DEUTZ

ENGINE MODEL NUMBER: F3L 912W

**********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 3.6

HORSEPOWER @ 25%= 15.8

HORSEPOWER @ 50%= 23.7

HORSEPOWER @ 75%= 40.0

HORSEPOWER @ 100%= 46.6

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.32

FUEL CONSUMPTION @ 2%= 6.17

FUEL CONSUMPTION @ 25%= 9.48

FUEL CONSUMPTION @ 50%= 11.90

FUEL CONSUMPTION @ 75%= 17.64

FUEL CONSUMPTION @ 100%= 20.28

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 8,17,2

CO,NOX,HC @ 2%= 24,80,7

CO,NOX,HC @ 25%= 18,151,5

CO,NOX,HC @ 50%= 17,182,5

CO,NOX,HC @ 75%= 22,240,4

CO,NOX,HC @ 100%= 28,247,5

14

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : DEUTZ
MODEL NUMBER : F3L 912W
RATED HORSEPOWER(TEST) = 46.6

2827 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.58467213
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=12.3577914
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.7596319
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=20.28

AT 12.5 HORSEPOWER CO(GM/HR)=19.6229508
AT 25 HORSEPOWER CO(GM/HR)=17.398773
AT 37.5 HORSEPOWER CO(GM/HR)=21.2331289
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER CO(GM/HR)=28

AT 12.5 HORSEPOWER NOX(GM/HR)=131.795082
AT 25 HORSEPOWER NOX(GM/HR)=186.625767
AT 37.5 HORSEPOWER NOX(GM/HR)=231.104295
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER NOX(GM/HR)=247

AT 12.5 HORSEPOWER HC(GM/HR)=5.54098361
AT 25 HORSEPOWER HC(GM/HR)=4.9202454
AT 37.5 HORSEPOWER HC(GM/HR)=4.15337423
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER HC(GM/HR)=5

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 53 (KGM) = 24

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 94

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 796

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 25

]

#14

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: ISUZU

ENGINE MODEL NUMBER: 4BD1

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.6

HORSEPOWER @ 25%= 20.5

HORSEPOWER @ 50%= 41.0

HORSEPOWER @ 75%= 61.5

HORSEPOWER @ 100%= 82.0

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.19

FUEL CONSUMPTION @ 2%= 4.72

FUEL CONSUMPTION @ 25%= 10.84

FUEL CONSUMPTION @ 50%= 17.64

FUEL CONSUMPTION @ 75%= 25.35

FUEL CONSUMPTION @ 100%= 34.61

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 9,25,8

CO,NOX,HC @ 2%= 127,60,73

CO,NOX,HC @ 25%= 122,177,90,

CO,NOX,HC @ 50%= 107,263,87

CO,NOX,HC @ 75%= 123,340,88

CO,NOX,HC @ 100%= 209,428,54

#15

```
** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

  COMPUTED DATA FOR ENGINE:
    MANUFACTURED BY : ISUZU
    MODEL NUMBER : 4BD1
    RATED HORSEPOWER(TEST) = 82
```

3856 cc

```
AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.24952382
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=12.3326829
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.4790244
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=21.0248781


AT 12.5 HORSEPOWER CO(GM/HR)=124.116402
AT 25 HORSEPOWER CO(GM/HR)=118.707317
AT 37.5 HORSEPOWER CO(GM/HR)=109.560976
AT 50 HORSEPOWER CO(GM/HR)=114.02439


AT 12.5 HORSEPOWER NOX(GM/HR)=127.47619
AT 25 HORSEPOWER NOX(GM/HR)=195.878049
AT 37.5 HORSEPOWER NOX(GM/HR)=248.317073
AT 50 HORSEPOWER NOX(GM/HR)=296.804878


AT 12.5 HORSEPOWER HC(GM/HR)=82.8042328
AT 25 HORSEPOWER HC(GM/HR)=89.3414634
AT 37.5 HORSEPOWER HC(GM/HR)=87.5121952
AT 50 HORSEPOWER HC(GM/HR)=87.4390244


FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
   1.7 HR. ENGINE OFF
   2.0 HR. ENGINE @ IDLE
   1.0 HR. ENGINE @ 12.5 HP
   3.0 HR. ENGINE @ 25.0 HP
   0.2 HR. ENGINE @ 37.5 HP
   0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 53 (KGM) = 24

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 531

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 844

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 393

]
```

15

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: ISUZU

ENGINE MODEL NUMBER: 4BC2

**********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.4

HORSEPOWER @ 25%= 18.0

HORSEPOWER @ 50%= 36.0

HORSEPOWER @ 75%= 54.0

HORSEPOWER @ 100%= 72.0

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.08

FUEL CONSUMPTION @ 2%= 6.48

FUEL CONSUMPTION @ 25%= 10.72

FUEL CONSUMPTION @ 50%= 18.30

FUEL CONSUMPTION @ 75%= 22.71

FUEL CONSUMPTION @ 100%= 29.76

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 9,25,9

CO,NOX,HC @ 2%= 116,163,66

CO,NOX,HC @ 25%= 127,177,75

CO,NOX,HC @ 50%= 113,265,46

CO,NOX,HC @ 75%= 121,361,60

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CO,NOX,HC @ 100%= 237,440,45

** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : ISUZU
MODEL NUMBER : 4BC2
RATED HORSEPOWER(TEST) = 72

3268 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=9.31518072
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.6677778
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=18.6675
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=21.73

AT 12.5 HORSEPOWER CO(GM/HR)=123.355422
AT 25 HORSEPOWER CO(GM/HR)=121.555556
AT 37.5 HORSEPOWER CO(GM/HR)=113.666667
AT 50 HORSEPOWER CO(GM/HR)=119.222222

AT 12.5 HORSEPOWER NOX(GM/HR)=172.361446
AT 25 HORSEPOWER NOX(GM/HR)=211.222222
AT 37.5 HORSEPOWER NOX(GM/HR)=273
AT 50 HORSEPOWER NOX(GM/HR)=339.666667

AT 12.5 HORSEPOWER HC(GM/HR)=72.0180723
AT 25 HORSEPOWER HC(GM/HR)=63.7222223
AT 37.5 HORSEPOWER HC(GM/HR)=47.1666667
AT 50 HORSEPOWER HC(GM/HR)=56.8888889

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 58 (KGM) = 26

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 540

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 944

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 296

]

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RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: ISUZU

ENGINE MODEL NUMBER: C240

**********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.0

HORSEPOWER @ 25%= 12.7

HORSEPOWER @ 50%= 25.5

HORSEPOWER @ 75%= 38.2

HORSEPOWER @ 100%= 51.0

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 0.39

FUEL CONSUMPTION @ 2%= 4.69

FUEL CONSUMPTION @ 25%= 8.53

FUEL CONSUMPTION @ 50%= 13.49

FUEL CONSUMPTION @ 75%= 18.52

FUEL CONSUMPTION @ 100%= 24.96

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 8,17,1

CO,NOX,HC @ 2%= 48,24,7

CO,NOX,HC @ 25%= 26,152,9

CO,NOX,HC @ 50%= 28,246,43

CO,NOX,HC @ 75%= 60,266,33

CO,NOX,HC @ 100%= 90,218,24

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : ISUZU
MODEL NUMBER : C240
RATED HORSEPOWER(TEST) = 51

2369 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.46435898
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.29625
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=18.2427559
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=24.456875

AT 12.5 HORSEPOWER CO(GM/HR)=26.3760684
AT 25 HORSEPOWER CO(GM/HR)=27.921875
AT 37.5 HORSEPOWER CO(GM/HR)=58.2362205
AT 50 HORSEPOWER CO(GM/HR)=87.65625

AT 12.5 HORSEPOWER NOX(GM/HR)=149.811966
AT 25 HORSEPOWER NOX(GM/HR)=242.328125
AT 37.5 HORSEPOWER NOX(GM/HR)=264.897638
AT 50 HORSEPOWER NOX(GM/HR)=221.75

AT 12.5 HORSEPOWER HC(GM/HR)=8.96581197
AT 25 HORSEPOWER HC(GM/HR)=41.671875
AT 37.5 HORSEPOWER HC(GM/HR)=33.5511811
AT 50 HORSEPOWER HC(GM/HR)=24.703125

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 55 (KGM) = 25

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 146

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 985

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 145

]

#17

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: FORD

ENGINE MODEL NUMBER: 6601(TEST DATA)

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 2.8

HORSEPOWER @ 25%= 22.26

HORSEPOWER @ 50%= 44.53

HORSEPOWER @ 75%= 66.69

HORSEPOWER @ 100%= 88.95

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 3.05

FUEL CONSUMPTION @ 2%= 5.78

FUEL CONSUMPTION @ 25%= 11.01

FUEL CONSUMPTION @ 50%= 17.44

FUEL CONSUMPTION @ 75%= 24.69

FUEL CONSUMPTION @ 100%= 34.85

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 35,38,16

CO,NOX,HC @ 2%= 68,53,46

CO,NOX,HC @ 25%= 56,156,39

CO,NOX,HC @ 50%= 55,305,40

CO,NOX,HC @ 75%= 188,426,36

CO,NOX,HC @ 100%= 558,472,7

18

```
** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

  COMPUTED DATA FOR ENGINE:
    MANUFACTURED BY : FORD
    MODEL NUMBER : 6601(TEST DATA)
    RATED HORSEPOWER(TEST) = 88.95

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.38693731
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=11.8011181
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=15.4102335
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=19.2295984


AT 12.5 HORSEPOWER CO(GM/HR)=62.0184995
AT 25 HORSEPOWER CO(GM/HR)=55.8769645
AT 37.5 HORSEPOWER CO(GM/HR)=55.3156713
AT 50 HORSEPOWER CO(GM/HR)=87.8298737


AT 12.5 HORSEPOWER NOX(GM/HR)=104.341213
AT 25 HORSEPOWER NOX(GM/HR)=174.332286
AT 37.5 HORSEPOWER NOX(GM/HR)=257.964975
AT 50 HORSEPOWER NOX(GM/HR)=334.86778


AT 12.5 HORSEPOWER HC(GM/HR)=42.5107914
AT 25 HORSEPOWER HC(GM/HR)=39.1230355
AT 37.5 HORSEPOWER HC(GM/HR)=39.6843287
AT 50 HORSEPOWER HC(GM/HR)=39.0126354


FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
   1.7 HR. ENGINE OFF
   2.0 HR. ENGINE @ IDLE
   1.0 HR. ENGINE @ 12.5 HP
   3.0 HR. ENGINE @ 25.0 HP
   0.2 HR. ENGINE @ 37.5 HP
   0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 54 (KGM) = 24

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 319

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 788

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 203

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4392 cc

18

```
RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: FORD

ENGINE MODEL NUMBER: 461Ø (ESTIMATE)

**********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 2.1

HORSEPOWER @ 25%= 16.7

HORSEPOWER @ 5Ø%= 33.4

HORSEPOWER @ 75%= 5Ø.Ø

HORSEPOWER @ 1ØØ%= 66.7

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 2.28

FUEL CONSUMPTION @ 2%= 4.33

FUEL CONSUMPTION @ 25%= 8.26

FUEL CONSUMPTION @ 5Ø%= 13.Ø8

FUEL CONSUMPTION @ 75%= 18.72

FUEL CONSUMPTION @ 1ØØ%= 26.14

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 26,28,12

CO,NOX,HC @ 2%= 51,4Ø,34

CO,NOX,HC @ 25%= 42,117,29

CO,NOX,HC @ 5Ø%= 41,228,3Ø

CO,NOX,HC @ 75%= 141,319,27

CO,NOX,HC @ 1ØØ%= 418,354,5
```

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : FORD
MODEL NUMBER : 4610 (ESTIMATE)
RATED HORSEPOWER(TEST) = 66.7

3294 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=7.12945205
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=10.6555689
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=14.4730121
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=18.72

AT 12.5 HORSEPOWER CO(GM/HR)=44.5890411
AT 25 HORSEPOWER CO(GM/HR)=41.502994
AT 37.5 HORSEPOWER CO(GM/HR)=65.6987952
AT 50 HORSEPOWER CO(GM/HR)=141

AT 12.5 HORSEPOWER NOX(GM/HR)=94.849315
AT 25 HORSEPOWER NOX(GM/HR)=172.167665
AT 37.5 HORSEPOWER NOX(GM/HR)=250.475904
AT 50 HORSEPOWER NOX(GM/HR)=319

AT 12.5 HORSEPOWER HC(GM/HR)=30.4383562
AT 25 HORSEPOWER HC(GM/HR)=29.497006
AT 37.5 HORSEPOWER HC(GM/HR)=29.2590361
AT 50 HORSEPOWER HC(GM/HR)=27

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 48 (KGM) = 21

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 248

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 749

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 151

]

19

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: HATZ

ENGINE MODEL NUMBER: 4L30 S/Z

**********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 6.3

HORSEPOWER @ 25%= 15.6

HORSEPOWER @ 50%= 31.3

HORSEPOWER @ 75%= 47.0

HORSEPOWER @ 100%= 62,6

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.14

FUEL CONSUMPTION @ 2%= 8.12

FUEL CONSUMPTION @ 25%= 10.39

FUEL CONSUMPTION @ 50%= 14.55

FUEL CONSUMPTION @ 75%= 19.30

FUEL CONSUMPTION @ 100%= 25.45

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 33,22,5

CO,NOX,HC @ 2%= 115,151,25

CO,NOX,HC @ 25%= 89,215,26

CO,NOX,HC @ 50%= 56,375,21

CO,NOX,HC @ 75%= 48,605,26

CO,NOX,HC @ 100%= 376,768,22

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : HATZ
MODEL NUMBER : 4L30 S/Z
RATED HORSEPOWER(TEST) = 62.6

2832 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=9.63333334
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=12.8807006
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.4257962
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=20.4826923

AT 12.5 HORSEPOWER CO(GM/HR)=97.6666667
AT 25 HORSEPOWER CO(GM/HR)=69.2420383
AT 37.5 HORSEPOWER CO(GM/HR)=52.8407643
AT 50 HORSEPOWER CO(GM/HR)=111.076923

AT 12.5 HORSEPOWER NOX(GM/HR)=193.666667
AT 25 HORSEPOWER NOX(GM/HR)=310.796178
AT 37.5 HORSEPOWER NOX(GM/HR)=465.828026
AT 50 HORSEPOWER NOX(GM/HR)=636.346154

AT 12.5 HORSEPOWER HC(GM/HR)=25.6666667
AT 25 HORSEPOWER HC(GM/HR)=23.0063694
AT 37.5 HORSEPOWER HC(GM/HR)=22.9745223
AT 50 HORSEPOWER HC(GM/HR)=25.2307692

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 55 (KGM) = 25

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 393

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1326

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 111

]

#20

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: HATZ

ENGINE MODEL NUMBER: D 108

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 5.5

HORSEPOWER @ 25%= 14.0

HORSEPOWER @ 50%= 28.5

HORSEPOWER @ 75%= 42.6

HORSEPOWER @ 100%= 56.5

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.22

FUEL CONSUMPTION @ 2%= 8.33

FUEL CONSUMPTION @ 25%= 8.74

FUEL CONSUMPTION @ 50%= 12.75

FUEL CONSUMPTION @ 75%= 17.19

FUEL CONSUMPTION @ 100%= 23.17

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 45,93,9

CO,NOX,HC @ 2%= 295,34,72

CO,NOX,HC @ 25%= 221,101,40

CO,NOX,HC @ 50%= 146,184,24

CO,NOX,HC @ 75%= 148,347,21

CO,NOX,HC @ 100%= 843,525,13

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : HATZ
MODEL NUMBER : D 108
RATED HORSEPOWER(TEST) = 56.5

3021 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.66764706
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=11.782069
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=15.5840426
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=20.3735971

AT 12.5 HORSEPOWER CO(GM/HR)=234.058824
AT 25 HORSEPOWER CO(GM/HR)=164.103448
AT 37.5 HORSEPOWER CO(GM/HR)=147.276596
AT 50 HORSEPOWER CO(GM/HR)=518

AT 12.5 HORSEPOWER NOX(GM/HR)=89.1764706
AT 25 HORSEPOWER NOX(GM/HR)=163.965517
AT 37.5 HORSEPOWER NOX(GM/HR)=288.042553
AT 50 HORSEPOWER NOX(GM/HR)=441.76259

AT 12.5 HORSEPOWER HC(GM/HR)=45.6470588
AT 25 HORSEPOWER HC(GM/HR)=27.862069
AT 37.5 HORSEPOWER HC(GM/HR)=22.0851064
AT 50 HORSEPOWER HC(GM/HR)=16.7410072

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 51 (KGM) = 23

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 897

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 868

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 153

]

21

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: HATZ

ENGINE MODEL NUMBER: 3L30 S/Z

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 4.9

HORSEPOWER @ 25%= 12.2

HORSEPOWER @ 50%= 24.5

HORSEPOWER @ 75%= 36.7

HORSEPOWER @ 100%= 48.9

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.04

FUEL CONSUMPTION @ 2%= 5.78

FUEL CONSUMPTION @ 25%= 7.49

FUEL CONSUMPTION @ 50%= 10.66

FUEL CONSUMPTION @ 75%= 14.33

FUEL CONSUMPTION @ 100%= 18.98

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 26,20,5

CO,NOX,HC @ 2%= 90,89,25

CO,NOX,HC @ 25%= 76,140,24

CO,NOX,HC @ 50%= 55,246,21

CO,NOX,HC @ 75%= 44,388,20

CO,NOX,HC @ 100%= 183,531,16

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : HATZ
MODEL NUMBER : 3L30 S/Z
RATED HORSEPOWER(TEST) = 48.9

2124 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=7.56731708
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=10.8104098
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=14.634918
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=18.98

AT 12.5 HORSEPOWER CO(GM/HR)=75.4878049
AT 25 HORSEPOWER CO(GM/HR)=54.5491804
AT 37.5 HORSEPOWER CO(GM/HR)=53.1147541
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER CO(GM/HR)=183

AT 12.5 HORSEPOWER NOX(GM/HR)=142.585366
AT 25 HORSEPOWER NOX(GM/HR)=251.819672
AT 37.5 HORSEPOWER NOX(GM/HR)=397.377049
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER NOX(GM/HR)=531

AT 12.5 HORSEPOWER HC(GM/HR)=23.9268293
AT 25 HORSEPOWER HC(GM/HR)=20.9590164
AT 37.5 HORSEPOWER HC(GM/HR)=19.7377049
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER HC(GM/HR)=16

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 46 (KGM) = 21

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 320

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1070

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 102

]

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RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: HATZ

ENGINE MODEL NUMBER: 2L40 S/Z

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 3.8

HORSEPOWER @ 25%= 9.5

HORSEPOWER @ 50%= 18.9

HORSEPOWER @ 75%= 28,6

HORSEPOWER @ 100%= 37.8

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 0.72

FUEL CONSUMPTION @ 2%= 4.82

FUEL CONSUMPTION @ 25%= 6.20

FUEL CONSUMPTION @ 50%= 8.86

FUEL CONSUMPTION @ 75%= 11.74

FUEL CONSUMPTION @ 100%= 15.32

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 19,19,15

CO,NOX,HC @ 2%= 56,77,8

CO,NOX,HC @ 25%= 74,173,12

CO,NOX,HC @ 50%= 48,284,11

CO,NOX,HC @ 75%= 36,430,11

CO,NOX,HC @ 100%= 181,518,11
```

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : HATZ
MODEL NUMBER : 2L40 S/Z
RATED HORSEPOWER(TEST) = 37.8

1716 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=7.04893617
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=10.671134
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=15.2032609
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=15.32

AT 12.5 HORSEPOWER CO(GM/HR)=65.7021277
AT 25 HORSEPOWER CO(GM/HR)=40.4536083
AT 37.5 HORSEPOWER CO(GM/HR)=176.271739
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER CO(GM/HR)=181

AT 12.5 HORSEPOWER NOX(GM/HR)=208.425532
AT 25 HORSEPOWER NOX(GM/HR)=375.814433
AT 37.5 HORSEPOWER NOX(GM/HR)=515.130435
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER NOX(GM/HR)=518

AT 12.5 HORSEPOWER HC(GM/HR)=11.6808511
AT 25 HORSEPOWER HC(GM/HR)=11
AT 37.5 HORSEPOWER HC(GM/HR)=11
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER HC(GM/HR)=11

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 45 (KGM) = 20

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 278

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 1528

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 77

]

23

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RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: KUBOTA

ENGINE MODEL NUMBER: V 4300-B

**********************INPUT TEST DATA**********************

 INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

 HORSEPOWER @ 2%= 1.6

 HORSEPOWER @ 25%= 20.0

 HORSEPOWER @ 50%= 40.0

 HORSEPOWER @ 75%= 60.0

 HORSEPOWER @ 100%= 79.0

 INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

 FUEL CONSUMPTION @ IDLE= 0.94

 FUEL CONSUMPTION @ 2%= 7.29

 FUEL CONSUMPTION @ 25%= 12.19

 FUEL CONSUMPTION @ 50%= 17.68

 FUEL CONSUMPTION @ 75%= 23.42

 FUEL CONSUMPTION @ 100%= 31.29

 INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

 CO,NOX,HC @ IDLE= 18,5,12

 CO,NOX,HC @ 2%= 151,17,55

 CO,NOX,HC @ 25%= 172,81,41

 CO,NOX,HC @ 50%= 136,220,31

 CO,NOX,HC @ 75%= 93,479,33

 CO,NOX,HC @ 100%= 347,678,32
```

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : KUBOTA
MODEL NUMBER : V 4300-B
RATED HORSEPOWER(TEST) = 79

4292 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=10.1927174
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.5625
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.99375
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=20.55

AT 12.5 HORSEPOWER CO(GM/HR)=163.440217
AT 25 HORSEPOWER CO(GM/HR)=163
AT 37.5 HORSEPOWER CO(GM/HR)=140.5
AT 50 HORSEPOWER CO(GM/HR)=114.5

AT 12.5 HORSEPOWER NOX(GM/HR)=54.9130435
AT 25 HORSEPOWER NOX(GM/HR)=115.75
AT 37.5 HORSEPOWER NOX(GM/HR)=202.625
AT 50 HORSEPOWER NOX(GM/HR)=349.5

AT 12.5 HORSEPOWER HC(GM/HR)=46.7065217
AT 25 HORSEPOWER HC(GM/HR)=38.5
AT 37.5 HORSEPOWER HC(GM/HR)=32.25
AT 50 HORSEPOWER HC(GM/HR)=32

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 58 (KGM) = 26

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 727

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 487

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 195

]

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RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: KUBOTA

ENGINE MODEL NUMBER: V 4000-B

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.4

HORSEPOWER @ 25%= 18.0

HORSEPOWER @ 50%= 36.0

HORSEPOWER @ 75%= 54.0

HORSEPOWER @ 100%= 72.0

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.08

FUEL CONSUMPTION @ 2%= 7.02

FUEL CONSUMPTION @ 25%= 11.26

FUEL CONSUMPTION @ 50%= 15.99

FUEL CONSUMPTION @ 75%= 21.20

FUEL CONSUMPTION @ 100%= 27.93

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 17,12,12

CO,NOX,HC @ 2%= 140,51,65

CO,NOX,HC @ 25%= 152,119,57

CO,NOX,HC @ 50%= 117,256,45

CO,NOX,HC @ 75%= 67,545,44

CO,NOX,HC @ 100%= 286,788,75

#25

```
** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

  COMPUTED DATA FOR ENGINE:
    MANUFACTURED BY : KUBOTA
    MODEL NUMBER : V 4000-B
    RATED HORSEPOWER(TEST) = 72
```

3983 cc

```
AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=9.85518073
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.0994444
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.4241667
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=20.0422222

AT 12.5 HORSEPOWER CO(GM/HR)=148.024096
AT 25 HORSEPOWER CO(GM/HR)=138.388889
AT 37.5 HORSEPOWER CO(GM/HR)=112.833333
AT 50 HORSEPOWER CO(GM/HR)=78.1111111

AT 12.5 HORSEPOWER NOX(GM/HR)=96.4698795
AT 25 HORSEPOWER NOX(GM/HR)=172.277778
AT 37.5 HORSEPOWER NOX(GM/HR)=280.083334
AT 50 HORSEPOWER NOX(GM/HR)=480.777778

AT 12.5 HORSEPOWER HC(GM/HR)=59.6506024
AT 25 HORSEPOWER HC(GM/HR)=52.3333333
AT 37.5 HORSEPOWER HC(GM/HR)=44.9166667
AT 50 HORSEPOWER HC(GM/HR)=44.2222222


FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
   1.7 HR. ENGINE OFF
   2.0 HR. ENGINE @ IDLE
   1.0 HR. ENGINE @ 12.5 HP
   3.0 HR. ENGINE @ 25.0 HP
   0.2 HR. ENGINE @ 37.5 HP
   0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 56 (KGM) = 25

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 627

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 741

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 254

]
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25

RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: PERKINS

ENGINE MODEL NUMBER: 4.2482

***********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 1.5

HORSEPOWER @ 25%= 19.7

HORSEPOWER @ 50%= 39.4

HORSEPOWER @ 75%= 59.4

HORSEPOWER @ 100%= 79.4

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.43

FUEL CONSUMPTION @ 2%= 7.23

FUEL CONSUMPTION @ 25%= 12.04

FUEL CONSUMPTION @ 50%= 18.01

FUEL CONSUMPTION @ 75%= 24.25

FUEL CONSUMPTION @ 100%= 31.53

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 18,17,14

CO,NOX,HC @ 2%= 107,62,58

CO,NOX,HC @ 25%= 96,112,53

CO,NOX,HC @ 50%= 77,175,33

CO,NOX,HC @ 75%= 56,280,21

CO,NOX,HC @ 100%= 92,384,15

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : PERKINS
MODEL NUMBER : 4.2482
RATED HORSEPOWER(TEST) = 79.4

4070 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=10.1371429
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.6461421
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=17.4342132
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=21.3172

AT 12.5 HORSEPOWER CO(GM/HR)=100.351648
AT 25 HORSEPOWER CO(GM/HR)=90.8883249
AT 37.5 HORSEPOWER CO(GM/HR)=78.8324873
AT 50 HORSEPOWER CO(GM/HR)=65.87

AT 12.5 HORSEPOWER NOX(GM/HR)=92.2197803
AT 25 HORSEPOWER NOX(GM/HR)=128.949239
AT 37.5 HORSEPOWER NOX(GM/HR)=168.923858
AT 50 HORSEPOWER NOX(GM/HR)=230.65

AT 12.5 HORSEPOWER HC(GM/HR)=54.978022
AT 25 HORSEPOWER HC(GM/HR)=47.6192893
AT 37.5 HORSEPOWER HC(GM/HR)=34.928934
AT 50 HORSEPOWER HC(GM/HR)=26.64

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 59 (KGM) = 27

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 431

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 569

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 235

]

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RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: PERKINS

ENGINE MODEL NUMBER: 4.2032

**********************INPUT TEST DATA**********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 0.7

HORSEPOWER @ 25%= 15.5

HORSEPOWER @ 50%= 30.6

HORSEPOWER @ 75%= 46.3

HORSEPOWER @ 100%= 61.6

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 1.04

FUEL CONSUMPTION @ 2%= 6.44

FUEL CONSUMPTION @ 25%= 10.91

FUEL CONSUMPTION @ 50%= 15.68

FUEL CONSUMPTION @ 75%= 21.32

FUEL CONSUMPTION @ 100%= 26.46

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 15,18,10

CO,NOX,HC @ 2%= 171,58,51

CO,NOX,HC @ 25%= 108,150,34

CO,NOX,HC @ 50%= 72,151,20

CO,NOX,HC @ 75%= 59,189,14

CO,NOX,HC @ 100%= 67,287,10

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : PERKINS
MODEL NUMBER : 4.2032
RATED HORSEPOWER(TEST) = 61.6

3328 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=10.0039189
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=13.9109934
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=18.1587261
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=22.5630065

AT 12.5 HORSEPOWER CO(GM/HR)=120.77027
AT 25 HORSEPOWER CO(GM/HR)=85.3509934
AT 37.5 HORSEPOWER CO(GM/HR)=66.2866242
AT 50 HORSEPOWER CO(GM/HR)=60.9346405

AT 12.5 HORSEPOWER NOX(GM/HR)=131.351351
AT 25 HORSEPOWER NOX(GM/HR)=150.629139
AT 37.5 HORSEPOWER NOX(GM/HR)=167.700637
AT 50 HORSEPOWER NOX(GM/HR)=212.699346

AT 12.5 HORSEPOWER HC(GM/HR)=37.445946
AT 25 HORSEPOWER HC(GM/HR)=25.192053
AT 37.5 HORSEPOWER HC(GM/HR)=17.3630573
AT 50 HORSEPOWER HC(GM/HR)=13.0326797

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 59 (KGM) = 27

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 426

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 674

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 137

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27

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RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **

ENGINE MANUFACTURED BY: PERKINS

ENGINE MODEL NUMBER: 4.154

**********************INPUT TEST DATA**********************

 INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

 HORSEPOWER @ 2%= 0.9

 HORSEPOWER @ 25%= 11.2

 HORSEPOWER @ 50%= 22.4

 HORSEPOWER @ 75%= 33.6

 HORSEPOWER @ 100%= 44.9

 INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

 FUEL CONSUMPTION @ IDLE= 1.01

 FUEL CONSUMPTION @ 2%= 4.63

 FUEL CONSUMPTION @ 25%= 8.09

 FUEL CONSUMPTION @ 50%= 11.04

 FUEL CONSUMPTION @ 75%= 14.15

 FUEL CONSUMPTION @ 100%= 18.92

 INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

 CO,NOX,HC @ IDLE= 34,6,5

 CO,NOX,HC @ 2%= 121,37,14

 CO,NOX,HC @ 25%= 68,73,7

 CO,NOX,HC @ 50%= 46,120,6

 CO,NOX,HC @ 75%= 37,138,4

 CO,NOX,HC @ 100%= 116,126,2
```

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```
** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

  COMPUTED DATA FOR ENGINE:
    MANUFACTURED BY : PERKINS
    MODEL NUMBER : 4.154
    RATED HORSEPOWER(TEST) = 44.9
```

2500 cc

```
AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.43241072
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=11.7619643
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=15.7962832
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=18.92


AT 12.5 HORSEPOWER CO(GM/HR)=65.4464286
AT 25 HORSEPOWER CO(GM/HR)=43.9107143
AT 37.5 HORSEPOWER CO(GM/HR)=64.2654867
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER CO(GM/HR)=116


AT 12.5 HORSEPOWER NOX(GM/HR)=78.4553572
AT 25 HORSEPOWER NOX(GM/HR)=124.178571
AT 37.5 HORSEPOWER NOX(GM/HR)=133.858407
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER NOX(GM/HR)=126


AT 12.5 HORSEPOWER HC(GM/HR)=6.88392857
AT 25 HORSEPOWER HC(GM/HR)=5.53571429
AT 37.5 HORSEPOWER HC(GM/HR)=3.30973451
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER HC(GM/HR)=2


FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
   1.7 HR. ENGINE OFF
   2.0 HR. ENGINE @ IDLE
   1.0 HR. ENGINE @ 12.5 HP
   3.0 HR. ENGINE @ 25.0 HP
   0.2 HR. ENGINE @ 37.5 HP
   0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 50 (KGM) = 23

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 289

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 502

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 34

]
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RUN
**SCIENCE APPLICATIONS INC.--DIESEL ENGINE PROGRAM **
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ENGINE MANUFACTURED BY: CONTINENTAL

ENGINE MODEL NUMBER: TMD 20 (ESTIMATED)

***********************INPUT TEST DATA***********************

INPUT CORRECTED TEST HORSEPOWER FOR RATED LOADS

HORSEPOWER @ 2%= 0.9

HORSEPOWER @ 25%= 11.25

HORSEPOWER @ 50%= 23.17

HORSEPOWER @ 75%= 34.27

HORSEPOWER @ 100%= 46.05

INPUT SPECIFIC FUEL CONSUMPTION(LBS/HR) FOR RATED LOADS

FUEL CONSUMPTION @ IDLE= 0.52

FUEL CONSUMPTION @ 2%= 4.87

FUEL CONSUMPTION @ 25%= 8.02

FUEL CONSUMPTION @ 50%= 11.17

FUEL CONSUMPTION @ 75%= 14.92

FUEL CONSUMPTION @ 100%= 20.32

INPUT EMISSIONS: CO,NOX,HC (GM/HR) FOR RATED LOADS

CO,NOX,HC @ IDLE= 8.6,2.0,3.0

CO,NOX,HC @ 2%= 73.3,12.0,21.0

CO,NOX,HC @ 25%= 40.7,40.1,8.0

CO,NOX,HC @ 50%= 24.4,84,8,2.6

CO,NOX,HC @ 75%= 27.7,122.5,1.9

CO,NOX,HC @ 100%= 78.2,133.7,4.6

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** SCIENCE APPLICATIONS INC.-- DIESEL ENGINE PROGRAM **

COMPUTED DATA FOR ENGINE:
MANUFACTURED BY : CONTINENTAL
MODEL NUMBER : TMD 20 (ESTIMATED)
RATED HORSEPOWER(TEST) = 46.05

2000 cc

AT 12.5 HORSEPOWER FUEL FLOW(LBS/HR)=8.35032718
AT 25 HORSEPOWER FUEL FLOW(LBS/HR)=11.7882432
AT 37.5 HORSEPOWER FUEL FLOW(LBS/HR)=16.4006452
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER FUEL FLOW(LBS/HR)=20.32

AT 12.5 HORSEPOWER CO(GM/HR)=38.9906879
AT 25 HORSEPOWER CO(GM/HR)=24.9440541
AT 37.5 HORSEPOWER CO(GM/HR)=41.5467742
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER CO(GM/HR)=78.2

AT 12.5 HORSEPOWER NOX(GM/HR)=44.7875
AT 25 HORSEPOWER NOX(GM/HR)=91.0154054
AT 37.5 HORSEPOWER NOX(GM/HR)=125.570968
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER NOX(GM/HR)=133.7

AT 12.5 HORSEPOWER HC(GM/HR)=7.43372483
AT 25 HORSEPOWER HC(GM/HR)=2.4845946
AT 37.5 HORSEPOWER HC(GM/HR)=2.64032258
**ENGINE RATED HP IS < 50 : VALUE SHOWN FOR 50HP IS 100% RATED VALUE
AT 50 HORSEPOWER HC(GM/HR)=4.6

FORKLIFT OPERATING CYCLE FOR AN 8 HOUR SHIFT IS:
1.7 HR. ENGINE OFF
2.0 HR. ENGINE @ IDLE
1.0 HR. ENGINE @ 12.5 HP
3.0 HR. ENGINE @ 25.0 HP
0.2 HR. ENGINE @ 37.5 HP
0.1 HR. ENGINE @ 50.0 HP

TOTAL FUEL USED PER SHIFT(LBS) = 50 (KGM) = 22

TOTAL CO PRODUCED PER SHIFT(GRAMS) = 147

TOTAL NOX PRODUCED PER SHIFT(GRAMS) = 360

TOTAL HC PRODUCED PER SHIFT(GRAMS) = 21

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END

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